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U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
ANIMAL HUSBANDRY RESEARCH DIVISION
and
COOPERATING WESTERN STATES

W-1 - IMPROVEMENT OF BEEF CATTLE THROUGH THE APPLICATION OF

BREEDING METHODS

1958 Annual Report of W-1

and

Report of

Annual Meeting of Technical Committee

Tucson, Arizona

July 7 - 10, 1958

This report is intended for the use of
administrative leaders and workers and
is NOT for general publication.

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL HUSBANDRY RESEARCH DIVISION
CURRENT SERIAL RECORDS

JUL 31 1958

U.S. D. A.
ANIMAL HUSBANDRY
RESEARCH DIVISION

ANNUAL MEETING
W-1 Technical Committee
Tucson, Arizona
July 7 - 10, 1958

R. L. Blackwell, Chairman

Project Leaders Present:

Arizona	O. F. Pahnish
California	P. W. Gregory
Colorado	H. H. Stonaker
Hawaii	E. H. Cobb
Idaho ,	R. E. Christian
Montana	F. S. Willson
Nevada	J. F. Kidwell
New Mexico	R. L. Blackwell
Oregon	Ralph Bogart
Utah	J. A. Bennett
Washington	C. C. O'Mary
Wyoming	P. O. Stratton

Regional Administrative Adviser S. S. Wheeler

Acting Western Regional Coordinator C. E. Shelby

Agricultural Research Service:

Animal Husbandry Research Division

Director R. E. Hodgson

Acting Chief, Beef Cattle Research Branch E. J. Warwick

State Experiment Stations Division M. J. Burris

The meeting was called to order at 8:15 A.M., July 7, by Dr. R. L. Blackwell. Two new committee members, Dr. Estel H. Cobb of Hawaii and Dr. Clayton C. O'Mary of Washington, members of the host institution, and guests were introduced.

Station reports were called for.

UNIVERSITY OF ARIZONA

- I. Station: Arizona Agricultural Experiment Station, Tucson, Arizona
- II. Project Title: Breeding and selection of beef cattle for the Southwest
- III. Personnel:
 - Experiment Station:
 - O. F. Pahnish, C. B. Roubicek, E. B. Stanley, G. E. Nelms, and E. S. Erwin
 - Graduate Students:
 - Richard H. Diven
 - Harry H. Synar
 - Cooperators:
 - Empire Ranch, Sonoita, Arizona
 - Arivaca Ranch, Arivaca, Arizona
 - Apache Indian Agency and Apache Tribe, San Carlos, Arizona
 - Montana Agricultural Experiment Station, Bozeman, Montana
 - Oregon Agricultural Experiment Station, Corvallis, Oregon
 - U. S. Range Livestock Experiment Station, Miles City, Montana
 - U. S. Department of Agriculture:
 - R. T. Clark, Coordinator
 - C. E. Shelby

IV. Nature and Extent of Work Done This Year:

Empire and Arivaca Herds

The accumulation of performance data as outlined in the Arizona project was continued.

Through the joint efforts of the Arizona and Oregon Agricultural Experiment Stations, weaning weights obtained during the first six years the project was in force were analyzed statistically. The major variables evaluated were: (1) weaning age of calf, (2) age of dam, and (3) sex of calf. Correction factors to adjust weaning weights for these variables were determined. Estimates of the heritability of weaning weight within sexes were calculated.

Conformation and condition scores obtained on the weanling calves of both ranches from 1952 through 1954 were analyzed within sexes. Conformation scores were correlated with condition scores, and both conformation and condition scores were correlated with weaning weights. The correlations between traits were phenotypic correlations.

Apache Tribal Herd

The breeding project conducted in cooperation with the Apache Tribe at San Carlos, Arizona, was continued under the provisions of the project agreement signed in 1955.

During the 1957 breeding season, five bulls from the Miles City station and four bulls produced in the Tribal herd were bred to about 30 cows each for the 1958 calf crop.

The following data and samples were obtained from the calves produced in 1957:

- Birth weights

- Weaning weights, conformation scores, and condition scores

- Liver samples at weaning age

- Liver samples and blood samples at approximately 12 months of age

- Monthly range forage samples from the pastures supporting the 1957 calves since weaning time have been collected for analysis

Dwarf Studies, University Test Herd

Since the Arizona station was no longer in a position to maintain the herd of heterozygous cows used in the dwarf study in cooperation with the New Mexico station, this study was discontinued.

V. Summary of Progress and Conclusions to Date:

Empire and Arivaca Herds

The influences of age at weaning, age of dam, and sex of calf on weaning weights of 329 bull calves and 332 heifer calves were determined. Estimates of the heritability of weaning weights within sexes were calculated by paternal half-sib correlations. Eleven sires were involved.

Growth within sexes, ranches, and years was essentially linear between the ages of 121 and 323 days. An average regression coefficient was therefore calculated within each sex for use as a weight-for-age adjustment factor. Each of these average coefficients was significant at the 1 percent level. The average regression coefficients were:

Sex	Av. Regression Coeff. and 95% Conf. Intervals
Bulls	1.442** $\pm$ 0.146
Heifers	1.090** $\pm$ 0.120

(** Significant at 1 percent level.)

1. The average regression coefficients differed significantly at the 1 percent level of probability, thus indicating the desirability of a weight-for-age adjustment factor for calves of each sex.
2. Differences among the regression coefficients calculated for the ranch-within-year subclasses for each sex were insignificant. It was therefore concluded that the average regression coefficients calculated within sexes should be reasonably useful weight-for-age adjustment factors under conditions similar to those involved in this study.
3. About 50 percent of the variation in uncorrected weaning weights of calves of each sex within ranches within years was removed by adjusting the weights to the constant age of 270 days by means of the average regression coefficients reported.

Age of dam exerted significant curvilinear influence upon the age-adjusted weaning weights of both bull and heifer calves. Three-year-old cows weaned the lightest calves. Calves produced by four- and nine-year-old cows were comparable and intermediate in weight at weaning time. The cows that were five, six, seven, and eight years of age produced the heaviest bull calves. With the exception of the eight-year-olds, cows of these latter ages also produced the heaviest heifer calves. Although eight-year-old cows produced heifer calves that were somewhat light in weight at weaning time, this was believed to be the result of chance variation. Correction factors proposed for the adjustment of 270-day weaning weights to a constant age-of-dam basis were:

Age of Dam (Years)	Correction (Lbs.)	
	Bulls (add)	Heifers (add)
3	50	24
4 and 9	25	12
5 to 8	0	0

1. Age of dam exerted a significantly greater influence upon the age-adjusted weaning weights of bull calves than upon those of the opposite sex. A single set of correction factors for calves of both sexes was therefore considered inapplicable.

2. The proposed age-of-dam adjustment factors accounted for about 14 and 4 percent of the on-ranch-within-year variation in age-adjusted weaning weights of bull and heifer calves, respectively.
3. Age of dam influences upon the weaning weights of the bull calves differed significantly among the ranch-within-year subclasses. Methods of calculating variable age-of-dam adjustment factors are therefore receiving consideration.
4. Age of dam influences on the weaning weights of heifer calves did not differ significantly among ranch-within-year subclasses.

The weaning weights of bull and heifer calves, adjusted for age of calf and age of dam, differed significantly at the 1 percent level of probability. The differences ranged from 44 to 99 pounds on Ranch I which was over a six-year period and from 53 to 77 pounds on Ranch II, over a three-year period. Because of the variability of sex differences in weaning weights and because of the significant interactions subsequently mentioned, a constant sex correction factor was considered to be of questionable value. It was concluded that the difference between the mean weaning weights of bull and heifer calves within ranches and years, after adjustment for age of calf and age of dam, should be a reasonably reliable sex correction factor under conditions similar to those involved in this study.

1. The analysis of the data collected at the Ranch I from (1949-1954) revealed a highly significant sex-year interaction. This was not true when the combined data from the two ranches were analyzed, but the latter analysis covered a period of only three years (1952-1954).
2. A significant sex-ranch interaction was obtained (5 percent level).
3. There was no significant sex-sire interaction within ranches and years.
4. The great variability of sex differences in weaning weights was presumed to be due to different physiological responses of the sexes to changing environments or to pasture differences associated with the necessary segregation of the sexes prior to weaning because some of the older calves reached the age of puberty. While the effects of segregation were not subject to statistical evaluation, the pastures used within ranches were believed to be comparable.

Estimates of the heritability of weaning weight were determined within sexes by paternal half-sib correlations. The weights were adjusted for differences in age at weaning and age of dam prior to the analyses summarized in tables 1 and 2.

1. The estimate of the heritability of weaning weight for bull calves was 28 percent (table 1) and the estimate for heifer calves was 57 percent (table 2). Because of the wide overlap of 95 percent confidence intervals (tables 1 and 2), the difference between these two estimates was considered to be insignificant.
2. Year effects accounted for approximately 11 and 16 percent of the variation in the weaning weights of bull and heifer calves, respectively, after the weights were adjusted for differences in weaning age and age of dam.
3. Ranch effects accounted for about 15 percent of the variation in the weaning weights of bull calves following adjustments for differences in weaning age and age of dam, but ranch effects did not contribute to the variation in the weaning weights of heifer calves.

Phenotypic correlations between weanling traits (weaning weights, conformation scores, and condition scores) were reported in a Master's thesis at the University of Arizona. These correlations were derived from the records of 164 bull calves and 161 heifer calves produced on the Empire and Arivaca ranches from 1952 through 1954. Heritabilities of conformation and condition scores were estimated by paternal half-sib correlations within sexes.

Table 1.--Variance analysis and estimated heritability of weaning weight of bull calves

Source of Variation	Sums of Squares	D. F.	Mean Squares	Expected Mean Squares
Total	1,027,129	328	3,131.49	$V_e + 11.663V_s + 40.459V_r + 55.316V_y$
Between years	216,133	5	43,226.60	$V_e + 11.725V_s + 40.727V_r + 54.737V_y$
Between ranches within years	54,393	3	18,131.00	$V_e + 11.906V_s + 28.302V_r$
Between sires within ranches and years	89,503	23	3,891.43*	$V_e + 9.690V_s$
Within sires within ranches and years	667,100	297	2,246.13	V_e
Variance Component	Calculated Variance	Per-cent	Heritability estimate with 95% confidence interval	
Error (V_e)	2,246.13	69	$= \frac{4V_s}{V_s + V_e} = 0.28 \pm 0.32$	
Sires (V_s)	169.79	5		
Ranches (V_r)	489.84	15		
Years (V_y)	347.76	11		
Total (V_e)	3,253.52	100		

*Statistically significant at the 5 percent level of probability

Table 2.--Variance analysis and estimated heritability of weaning weight of heifer calves.

Source of Variation	Sums of Squares	D.F.	Mean Squares	Expected Mean Squares
Total	747,112	331	2,257.14	$V_e + 12.795V_s + 41.349V_r + 55.572V_y$
Between years	128,371	5	25,674.20	$V_e + 12.658V_s + 41.363V_r + 55.286V_y$
Between ranches within years	14,314	3	4,771.33	$V_e + 12.445V_s + 27.945V_r$
Between sires within ranches and years	100,124	23	4,353.22**	$V_e + 9.504V_s$
Within sires within ranches and years	504,303	300	1,681.01	V_e
Variance Component	Calculated Variance	Per-cent.	Heritability estimate with 95% confidence interval	
Error (V_e)	1,681.01	72	$= \frac{4V_s}{V_s + V_e} = 0.57 \pm 0.41$	
Sires (V_s)	281.17	12		
Ranches (V_r)	-14.63	0		
Years (V_y)	380.55	16		
Total (V_t)	2,328.10	100		

** Statistically significant at the 1 percent level of probability

The correlations between weanling traits are shown in table 3. The conformation and condition scores involved in these correlations were averages of the scores assigned by three judges.

1. Heifer calves tended to vary less and score higher in conformation than did bull calves. In all but one of the ranch-year subclasses, the average condition scores of the heifers were also higher than those of bull calves.

Table 3.--Average phenotypic correlations between weanling traits

	Condition Score	Actual Weaning Weight	Adjusted Weaning Weight
Bull calves:			
Conformation score	.62	.20	.28
Condition score	--	.52	.54
Heifer calves:			
Conformation score	.70	.37	.42
Condition score	--	.60	.57

2. High positive correlations between conformation and condition scores were obtained within sexes.
3. Reasonably high positive correlations were obtained between condition scores and weaning weights.
4. Conformation scores and weaning weights were positively correlated to some degree even though the members of the scoring committee were advised to ignore size or weights to the best of their abilities.
5. There were indications that the scoring committee was inclined to score on a relative basis within ranches and years.
6. The members of the scoring committee agreed more closely in their evaluations of condition than in their evaluations of conformation.

Estimates of the heritabilities of conformation and condition scores were as follows:

Sex	Heritabilities	
	Conformation	Condition
Bulls	0	0
Heifers	.39	.24

Apache Tribal Herd

The calving data accumulated during the calving season of 1957 were discussed in the annual report covering the period from July 1, 1956, to June 30, 1957. All calving records for 1958 were not available for inclusion in the current report, but a preliminary estimate indicates that the calf crop (calves born alive/cows bred) should exceed 80 percent. The analogous figure for 1957 was 68 percent.

The weights, conformation scores, and condition scores obtained to date on the 1957 calf crop have not been analyzed statistically to date.

Laboratory analyses of the following blood and liver constituents are in various stages of completion:

Blood	Liver
Vitamin A	Vitamin A
Carotene	Carotene
Hemoglobin	Dry matter
Creatinine	Copper
Cholesterol	Molybdenum
Calcium	Iron
Phosphorus	
Glucose	
Uric acid	

The liver samples were collected at weaning time and again when the 1957 calves were weighed and scored at approximately twelve months of age. Blood samples were taken on the latter date only.

VI. Work Planned for the Future:

The program in cooperation with the Empire and Arivaca ranches will be continued. Analyses of the 18-month weights, conformation scores, and condition scores accumulated over the first six years, are scheduled for the fiscal year 1958-59.

The cooperative program on the Apache Reservation will be continued and expanded. Twelve sires were used during the 1958 breeding season as compared to 9 sires in each of the two previous years. Weights, conformation scores, condition scores, liver samples, and blood samples will be obtained at weaning time and when the calves reach approximately 12, 18, and 24 months of age. Analyses of range forage samples (collected monthly) should assist in the evaluation of range environment. Evaluations of the relationships between genetic and nutritional influences in the Apache herd will receive priority.

VII. Publications and Manuscripts:

Pahnish, O. F., Ralph Bogart, E. B. Stanley, C. B. Roubicek, and C. E. Shelby. 1958. Adjustment of weaning weights of range calves to a standard age of 270 days. Amer. Soc. Anim. Prod. West. Sect. Proc. 9:XLVII-1.

Pahnish, O. F., C. B. Roubicek, E. B. Stanley, Ralph Bogart, and C. E. Shelby. 1958. The influence of age of dam on the 270-day weaning weights of bull and heifer calves. Amer. Soc. Anim. Prod. West. Sect. Proc. 9:XLVIII-1.

Synar, Harry H. 1958. The relationships of weaning production factors in range beef cattle. M. S. Thesis, University of Arizona.

Cattle Inventory
Purebreds

PROJECT SUMMARY
Arizona Agricultural Experiment Station

Breed	Hereford	Hereford	Hereford
Herd designation	Empire	Arivaca	Apache
Bulls (12 mos. or over)	4	4	83
Cows (12 yrs. or over)	80	80	300
Heifers, yearlings	33	27	74
Bull calves ^{1/}	30	30	115
Heifer calves ^{1/}	30	30	115
Estimated cash value ^{2/}	\$45,400	\$43,900	\$180,000

^{1/} Preliminary figures, 1958.

^{2/} Cooperative projects. No accurate method of determining percentage used for breeding project.

Land, Physical Facilities, and Equipment Used

Item	Number	Actual Cash Value	Percentage Used for Beef Breeding Project ^{1/}
Empire Ranch:			
Land	7 sections	\$32,330	
Fencing	18 miles	9,000	
Corrals and scales		4,000	
Water supply		3,000	
Total		48,330	
Arivaca Ranch:			
Land	7 sections	32,330	
Fencing	18 miles	9,000	
Corrals and scales		4,000	
Water supply		3,000	
Total		48,330	
Apache Reservation:			
Land	35 sections	103,000	
Fencing	50 miles	20,000	
Corrals and scales		4,000	
Water supply		12,000	
Total		139,000	
Experiment Station:			
Laboratory facilities		15,000	20

^{1/} Owned by private operators. No accurate method of determining percentage used for breeding project.

Cow Production Data^{1/} Arizona Agricultural Experiment Station

Breed	Hereford				Hereford				Hereford			
Line	Empire				Arivaca				Apache			
Cows bred	67				59				242			
Calves born												
Alive	60				49				164			
Dead	3				4				3			
Total	63				53				167			
Calves weaned	57				48*				150			
% calf crop												
Birth ^{2/}	90				83				68			
Weaning ^{3/}	85				81				62			

	Bulls		Heifers		Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average												
Birth weight	--	--	--	--	--	--	--	--	82	84.3	82	78.4
Weaning age		274		279		273		268		213		214
Weaning wt.	24	486	33	458	18	514	27	453	76	410	74	397
Wean. wt. ^{4/}		500		458		524		467		408		393
Weaning score												
Cond.	24	11.4	33	11.5	18	11.0	27	11.3	--	--	--	--
Conf. ^{5/}	24	11.2	33	11.3	18	11.5	27	11.3	76	10.0	74	11.0

^{1/} 1957 calf crops.

^{2/} Calves born alive/cows bred.

^{3/} Calves weaned/cows bred.

^{4/} Weaning weights of Empire and Arivaca calves adjusted to 270 days of age, and weights of Apache calves adjusted to 205 days. All weights adjusted to 7-year-old age-of-dam basis.

^{5/} Score of 11 is middle-choice feeder grade.

* Weaning records were not obtainable on three of these calves.

UNIVERSITY OF CALIFORNIA

- I. Station: California Agricultural Experiment Station, Davis, California
- II. Project Title: Genetic control of hereditary deficiencies in beef cattle with special emphasis upon dwarfism
- III. Personnel:
 - Experiment Station:
 - P. W. Gregory, F. D. Carroll, C. F. Lofgreen, L. M. Julian, W. S. Tyler, T. J. Hage, L. M. Holm, P. C. Kennedy, J. P. Hughes, Iola Felhaber, A. Aguirre
 - U. S. Department of Agriculture:
 - R. T. Clark, Coordinator
 - C. E. Shelby
- IV. and V. Nature and Extent of Work Done This Year, and Summary of Progress and Conclusions to Date:

Genetic and anatomical investigations continue to support the hypothesis that:

 - a. Dwarfism is a complex of several components,
 - b. A major dwarf conditioning gene with modifiers at two or more loci with unique factor interactions is indicated,
 - c. The progeny test on the basis of one dwarf conditioning gene is unreliable,
 - d. All brachycephalic dwarfs observed manifest premature closure of the spheno-occipital synchondrosis and also can be consistently differentiated by three metacarpal indices,
 - e. Histological studies of epiphyseal cartilage also indicate that the brachycephalic dwarf suffers from achondroplasia,
 - f. Seven "comprest" type animals between 8 and 17 months of age have been found with closure or partial closure of the spheno-occipital synchondrosis, which suggests that "comprest" animals may be divided into two subgroups.

Progress has been made in the development of definite criteria to differentiate between specific cattle populations. These criteria employ body weight, body measurements, body proportions, specific bone proportions, ossification patterns, and ossification time.

Application of Findings: These results are of a basic nature in that objective methods are being developed to separate different populations and mutant types. This should contribute to the refinement of techniques concerned with studies of growth, size, conformation, heterosis, and herd deterioration.

VI. Work Planned for the Future:

Genetics

1. Use brachycephalic and/or "comprest" cows that have produced brachycephalic dwarf calves to determine the relationships of other aberrant types to the dwarf complex.
2. Test bull D8, subnormal in size, from Oregon station, that produces a high percentage of small lethal calves, and a bull of normal size from the New Mexico station that sires extreme hydrocephalic calves.
3. Continue analysis of "comprest" and entire dwarf complex. The backcrossing of "synthetic comprest" to brachycephalic and dolichocephalic parents is being continued. An F_2 population from the mating of F_1 "synthetic comprest" animals is being produced.
4. The blood type of each animal in the herd is obtained. The possibility of linkage between immunogenetic factors and factors associated with the dwarf complex will be investigated.

Anatomy

Over 500 animals comprising mutant types and controls of normal size are now represented in the Anatomical Collection. Brachycephalic dwarfs and nonbrachycephalic dwarf controls are well represented. The effect of different dwarf types upon the dimensions of the facial and skull bones is being investigated. Many other mutant types are represented in the collection and these are being increased as rapidly as possible. When sufficient numbers of any one type become available, an anatomical analysis will be made.

Considerable attention is being directed toward the relationships of the size of organs and parts to total body size in all of the populations and mutant stocks. The size and volume of important muscles also is under investigation. Material is being assembled for comprehensive studies of allometric growth in different populations and mutant stocks.

Physiology and Biochemistry

Investigations are being made in physiology and biochemistry which center around:

- a. Reported increased sensitivity of brachycephalic dwarfs to insulin,
- b. Comparison of the function of the adrenal-pituitary axis in brachycephalic dwarfs to that of other components of the complex and in normal animals,

- c. Factors that produce degranulation of the hypophyseal acidophiles of various dwarf components and normal types,
- d. Comparison of the influence of ATCH and insulin upon the plasma, proteins, and lymphatic organs of the dwarf components and normal animals,
- e. Investigation of blood cellular elements of the dwarf components and normal animals,
- f. A study of target organs that may be influenced by the thyroid-pituitary axis.

Histopathology

Considerable attention will be devoted to the histopathology of the endocrine glands and any lesions that may be associated with specific phenomena and expression of dwarfism.

Clinical Studies

Somewhat detailed clinical studies are being undertaken in an effort to obtain a more complete understanding of the dwarfing processes involved. All clinical findings will be correlated, insofar as possible, with histopathology, anatomy, physiology, and biochemistry.

VII. Publications and Manuscripts:

Gregory, P. W., L. M. Julian, and W. S. Tyler. 1957. The validity of dwarf-carrier cows as testers for the major dwarf conditioning gene. (Abs.) J. Anim. Sci. 16(4):1028.

Tyler, W. S., L. M. Julian, and P. W. Gregory. 1957. The nature of the short-headed Hereford dwarf as revealed by gross examination of the appendicular skeleton. Amer. J. Anat. 101(3):477-496.

Tyler, W. S., L. M. Julian, L. Z. McFarland, H. E. Evans, and P. W. Gregory. 1958. Two projections into the cranial cavity associated with bovine dwarfism. (In manuscript.)

VIII. Project Summary:

Genetic and anatomical investigations continue to support the hypothesis that dwarfism is a complex of several components. A major dwarf conditioning gene with modifiers at two or more loci, with unique factor interactions, is indicated. The progeny test on the basis of one dwarf conditioning gene and one dwarf type is unreliable. All brachycephalic dwarfs observed manifest premature closure of the spheno-occipital synchondrosis, and also can be consistently differentiated by three metacarpal indices. Histological studies of epiphyseal cartilage also indicate that the brachycephalic dwarf suffers from achondroplasia. Seven

"comprest" type animals between 8 and 17 months of age have been found with closure or partial closure of the spheno-occipital synchondrosis. This suggests that "comprest" animals may be divided into two subgroups.

Progress has been made in the development of definite criteria to differentiate between cattle populations. These criteria employ body weight, body measurements, body proportions, specific bone proportions, ossification patterns, and ossification time.

Herd Inventory
June 10, 1958

	Number
1. Brachycephalic Dwarfs	
Females, breeding age	30
Females, yearlings	4
Bulls	2
2. Dolichocephalic Dwarfs	
Females, breeding age	16
Females, yearlings	3
Bulls	2
3. Intermediate Dwarfs	
Females, breeding age	3
Females, yearlings	3
4. Comprest Type	
Females, breeding age	-
Comprest (Descendents of Colorado Domino 68th)	6
Recurrent Comprest	8
Synthetic Comprest	7
Females, yearlings	3
Bulls, mature	2
5. Other Bulls	
Compact Shorthorn	1
Hereford OSC E22(8987085)	1
Hereford New Mexico A&M (Sires extreme hydrocephalous lethal calves)	1
6. To be Autopsied at 16 Months of Age	
Heifers, yearlings	19
Bulls, yearlings	18
7. 1958 Calves on Cows	
Heifers	23
Bulls	22

I. Station: California Agricultural Experiment Station, Davis,
California

II. Project Title: Breeding experiments to investigate the nature of
genetic improvement in beef cattle productivity with special empha-
sis on the performance of inbred lines and their crosses

III. Personnel:

Experiment Station:

W. C. Rollins, F. D. Carroll, N. R. Ittner, K. A. Wagon,
J. W. T. Pollock, K. Sittmann, and J. Tapia

U. S. Department of Agriculture:

R. T. Clark, Coordinator
C. E. Shelby

IV. Nature and Extent of Work Done This Year:

Testing bulls directly and by use of progeny for rate of gain, efficiency
of gain and earliness of maturity.

This experiment is continuing according to plan. Currently, 23 bulls
are being individually fed, 4 bulls are out in cooperator herds produc-
ing progeny test steers, and 40 steers are being fed at Davis in the
progeny testing of 4 bulls.

Data on growth during the suckling period are being gathered in the
purebred Hereford herd according to plan.

The double cervix study continues. Three double cervixes have been ob-
tained and arrangements are being made to obtain several more in the
near future. This collection will afford material for a study of pheno-
typic variation in the expression of this trait.

The fourth and last calf crop in the current Brahman-Hereford cross-
breeding experiment was weaned July 1957. Following weaning, these cows
were sold.

Five crossbreds and five Hereford heifers were put in the feed lot on
July 5, 1957. The remaining calves were run on summer pasture and put
in the feed lot October 1, 1957.

Rectal temperatures were taken during the summer in the same manner as
previous years.

The heifers going on feed in July were finished early in December. Body
measurements and slaughter and carcass data as previously described were
obtained. The remaining calves went to market in April 1958. The data

collected in this experiment will be reported in two or three manuscripts dealing with: (a) cow performance, (b) growth and performance of calves from birth to marketing, and (c) carcass and meats analyses.

A study of the heritabilities and genetic and environmental correlations of weaning weight and weaning grade is being undertaken.

Records on five thousand or more animals in purebred Hereford herds enrolled in the University of California Agricultural Extension Record of Performance Program comprise the material for study. These data are being put on IBM cards. The genetic and nongenetic parameters estimated will be used in a selection index study.

Line, line cross, and top cross comparisons of the California inbred Rover line with various Colorado inbred lines.

Last year's calf crop was composed of inbred Rover line calves sired by Bull 263 and Rover X Brae Arden crossline calves sired by Brae Arden Bull 4010.

Growth data to date for these calves are presented in Section V.

Rover line bulls 369 and 371 were sent to the Colorado Station in the Fall of 1957. One bull was then picked up by the Mississippi station. One bull was used in Colorado and the other in Mississippi during the 1958 breeding season. For the 1959 breeding season, these two bulls will be switched. This, along with the 1956 and 1957 breeding results, will give a comparison of the Rover and Brae Arden lines at Colorado and the Rover, Brae Arden, and Royal lines at Mississippi based on three bulls per line.

Rover bull 310, used at Colorado and Mississippi in the trials described above, was entered in a topcross test involving 10 bulls at the Coddling Brothers Ranch in Foraker, Oklahoma (1958 Breeding Season). These bulls include a representative from each of the Brae Arden and Royal lines.

At Davis two Rover bulls, 173 and 388, were used in natural service on the inbred and crossline cows and heifers. Twenty-three Rover inbreds were artificially bred to two Brae Arden bulls, eleven to Bull 3112, and twelve to Bull 5012. It is too early to know how many of these cows are settled.

If this artificial breeding has been sufficiently successful, then the comparison of crossline calves with Rover inbreds will be based on the offspring of three bulls from each line, rather than one bull per line.

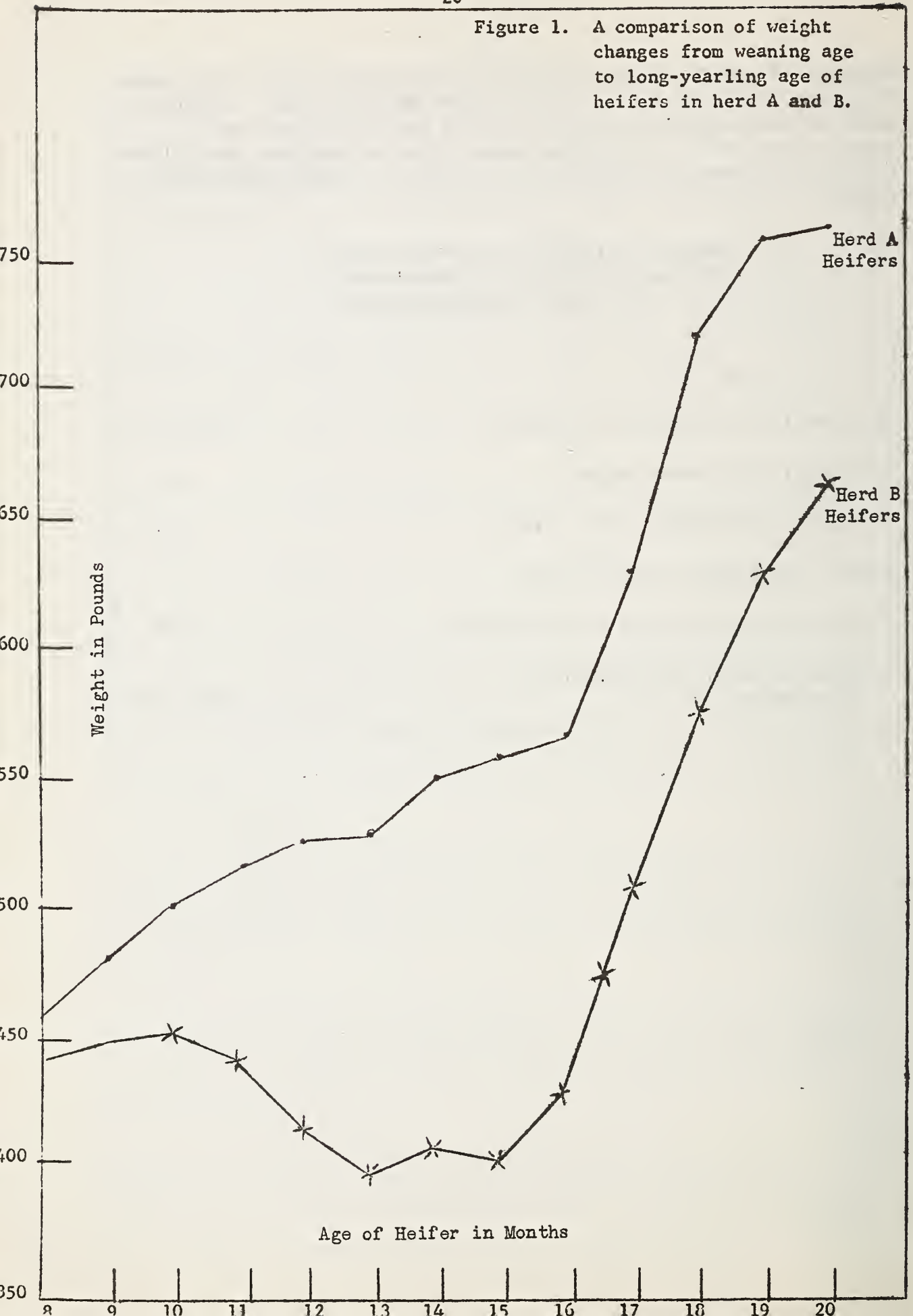
Further analysis of long yearling weights of range heifers.

Estimates of additional genetic parameters have been and are being made. The estimates already made are given in the following table. Slightly different estimates from those reported on page 40 of last year's report result from: (1) an error found in the calculations, and (2) deletion of two year-groups that were not replicated under both feeding regimes.

Estimates of Genetic and Environmental
Parameters for Herd A (Supplemented)
and for Herd B (Unsupplemented)

Estimate	Herd A	Herd B
Heritability of long-yearling weight	.42	0(-.23)
Heritability of weaning weight	.36	.42
Phenotypic correlation of LYW with WW	.68	.78
Genetic correlation of LYW with WW	.74	0
Environmental correlation of LYW with WW	.62	1.00
Heritability gain from weaning to long-yearling age	.25	0(-.04)

Figure 1. A comparison of weight changes from weaning age to long-yearling age of heifers in herd A and B.



Inspection of the above figure suggested that it would be interesting to divide the growth period from weaning to long-yearling age into two periods: (1) period from weaning to the lowest average weight date for Herd B, and (2) period from lowest average weight date for Herd B to long-yearling age. Corresponding temporal periods to be used for Herd A. Heritabilities for growth rate for each of these periods and the genetic and environmental correlations between these two traits are being estimated for Herds A and B.

V. Summary of Progress and Conclusions to Date:

Progeny Test Results

The trend noticed in the results of the first six progeny groups (see page 39 of last year's report) continues for the first 14 progeny groups tested. To better test this trend, the last four pairs of loan bulls have been chosen in such a way that the one pair member growing faster from weaning to feed-lot test is the slower gainer during the feed-lot test. Pair members also have been chosen as close to the same age as possible.

Bull Selection Criterion	Av. Performance in Feed Lot of the Progeny of:			
	Better Bulls		Poorer Bulls	
	Daily Gain	Feed Efficiency	Daily Gain	Feed Efficiency
	Lb./Day	Lb. TDN/100 Lb. Gain	Lb./Day	Lb./TDN/100 Lb. Gain
#1 Av. daily gain weaning to feed lot	2.40	527	2.32	545
#2 Av. daily gain in feed lot	2.34	543	2.39	530
#3 Feed efficiency in feed lot	2.40	527	2.32	545

The data in the above table along with performance data for the sires enable us to estimate heritabilities of rate of gain and feed efficiency.

$$\text{Heritability} = \frac{\left(\frac{\text{Progeny average of (better sires)}}{\text{Average performance of better sires}} \right) - \left(\frac{\text{Progeny average of (poorer sires)}}{\text{Average performance of poorer sires}} \right)}{\frac{1}{2}}$$

The factor $\frac{1}{2}$ is included because within each pair of bulls the cows were unselected, thus cutting the selection differential in half.

Using rate of gain of sires from weaning to feed lot to predict rate of gain of progeny in the feed lot we have:

$$\text{Heritability} = \frac{.08}{.09} = .89$$

Using efficiency of gain of sires in feed lot to predict efficiency of gain of progeny in feed lot we have:

$$\text{Heritability} = \frac{-18}{-27} = .67$$

Within all pairs, bulls were ranked the same by criteria #1 and #3.

If rate of gain from weaning (8 months of age) to about 12 or 14 months of age on a growing ration is to be used for the above purpose, it is of interest to note if enough variability in growth rate during such a period exists.

For the 60 bulls tested to date we have:

Average daily gain in feed lot in pounds 2.73 with an intra-year standard deviation of .205.

Average daily gain from weaning to feed lot 1.40 with an intra-year standard deviation of .215.

A Comparison of Inbred Rover Calves with
Brae Arden X Rover Calves

	Rover		Brae Arden X Rover	
	Bull	Heifer	Bull	Heifer
Number of calves	14	8	13	13
Av. 240-day weaning weight	505	446	514	450
Av. 240-day weaning weight adjusted for age of dam	515	453	525	464
Av. weaning grade (2 = 8.0) (2- = 7.0)	7.5	7.8	7.7	7.8
Av. yearling weight	679	694	741	732
Av. yearling age	369	443	377	449
Av. daily gain weaning to yearling age	1.37	1.24	1.73	1.37
Bulls on individual feed test				
Number	13		10	
Av. age at start of test	422		433	
Av. shrunk weight at start of test	688		761	
Av. gain for first 56 days of test	3.23		3.34	

The extended analysis of long-yearling weights of range heifers reported in section IV presents a set of estimates that suggests a greater importance for heterozygosity and a lesser importance of additively genetic effects under B herd than under A herd conditions. This conclusion is based upon consideration of environmental conditions in the two herds and upon the fact that in paternal half-sib estimates of heritability and genetic correlation dominance effects occur statistically in the term for random environmental effects.

Application of Findings

Additional analysis supports the previously stated conclusion that at long-yearling age heifers can be selected more effectively under a nutritional regime permitting continuous growth than under one where weight losses may be sustained some time between weaning and long-yearling age.

VI. Work Planned for the Future:

To compare inbred Rover bulls with bulls resulting from a cross of Rover and Brae Arden inbred lines.

Purpose: These crossline bulls show evidence of hybrid vigor. The proposed progeny tests would yield information on the relative merit of crossline and inbred bulls used in top crosses. Points of interest to compare in addition to the other things being studied will be percentage calf crop and uniformity and vigor in the calves.

During the 1959 breeding year, four Rover bulls and four Rover X Brae Arden crossline bulls will be available. A cooperator will take one each and mate each bull to 20-25 cows. One such pair has already been contracted.)

Such a cooperator would grow out five steers per bull to long-yearling age, at which time they would be sent to a commercial feed lot unless the cooperator had facilities to feed them.

Measurements to be gathered:

Live Animals:	Weaning weight
	Weaning grade
	Gain from weaning to feed lot (long yearling)
	Gain during feed-lot period
	Slaughter grade
Carcass:	Biopsy samples of muscles for texture
Packing House	Head and metacarpal bones
Vet. Sci.	Yield and grade (conformation and finish grade)
A.H. Dept.	Density
Davis	Eye muscle area
A.H. Dept.	External fat thickness
	Intramuscular fat - marbling
	Ratio of lean to bone

Jobbing House Cut-out values - relate to conformation and finish

Live-animal measurements to yearling or long-yearling age on heifer calves and the remaining steer calves will be obtained if the cooperator is able to identify individually and properly manage these additional animals.

This year Dr. Clyde Stormont will start routinely blood typing animals in the University of California Purebred Hereford herd.

VII. Publications and Manuscripts:

Rollins, W. C., and K. A. Wagnon. 1958. Genotype environment interaction in a beef cattle herd. Tenth International Congress of Genetics Proc. Vol. 1. (In press.)

Wagnon, K. A., and W. C. Rollins. 1957. A genetic analysis of long-yearling heifer weights in a range beef herd operated under optimum and suboptimum nutritional regimes. (Abs.) J. Anim. Sci. 16(4):1026.

Cattle Inventory PROJECT SUMMARY
Purebreds California Agricultural Experiment Station

Breed	Hereford	Hereford	
Line	Rover	Brae Arden X Rover	
Station	Davis	Davis	
Bulls (12 mos. or over)	35	12	
Cows (2 yrs. or over)	48		
Heifers, yearlings	3	12	
Bull calves	29		
Heifer calves	14		
Percentage used for breeding project	100	100	
Estimated cash value	\$49,800	\$9,600	
Grades			
Breed	Hereford	Braford	Hereford
Line			San Joaquin
Station	Imperial	Imperial	Experimental
Bulls (12 mos. or over)			Range
Cows (2 yrs. or over)			151
Steer calves	4	10)	120
Heifer calves	9	10)	
Percentage used for breeding project	100	100	25
Estimated cash value	Slaughtered before May		\$50,000

California Agricultural Experiment Station

Young Animals on Feed

Purebreds

	Hereford		Braford	
	Number individually fed	Number group fed	Number individually fed	Number group fed
Bulls	23			
Heifers				
Steers				
Grades				
Bulls				
Heifers		9		10
Steers		44		10

Land, Physical Facilities, and Equipment Used

Item	Number	Actual Cash Value	Percentage Used for Breeding Project
Davis:			
Barns and corrals	3	\$100,000	75
Irrigated pasture	45 acres		100
Dry lots	15 acres		100
Imperial:			
Barns and corrals	1	25,000	50
Irrigated pasture	160 acres		50
San Joaquin:			
Corrals, scales and other facilities for handling beef cattle	2	30,000	25
Foothill range	5,000 acres		25

Breed	Hereford					
Line	Rover X Brae Arden					
Cows bred	28					
Calves born	29					
Alive	26					
Dead	2					
Total	28					
Calves weaned	26					
% calf crop						
Birth	89.3					
Weaning	89.7					
* Includes 1 set twins						

	Bulls		Steers		Heifers	
	No.	Av.	No.	Av.	No.	Av.
Average Birth weight	16	75.1	-	-	10	62.7
Weaning age	240.1		-		247.9	
Weaning wt.	14	503.9	-	-	8	451.9
Adj. weaning wt.-240 dys	505.1		-		446.4	
Weaning score						
Cond.	-	-	-	-	-	-
Conf.	-	-	-	-	-	-

Feed Lot Performance California Agricultural Experiment Station

Breed	Hereford	Hereford	Hereford	Braford	Hereford	Braford
Line	Rover	Grade	Grade-Imperial	Grade	Grade-Imperial	Grade
Sex	Bulls	Steers	Steers	Steers	Heifers	Heifers
Number on test	17	39	4	9	5 4	5 5
Average			October	October	July Oct.	July Oct.
Age on test	395	Short yearling	331	308	250 315	247 330
Initial weight	740.4	594.8	615	587	498 478	536 549
Initial score						
Cond.	Commercial					
Conf.						
Days on test	112*	139	178	178	156 173	156 173
Gain						
Total	234.4	308.4	396	359	317 370	324 329
Average	2.79	2.22	2.23	2.02	2.03 2.08	2.06 1.85
Efficiency of feed utilization						
#TDN/100# gain or # Gain/100# TDN	481	553	524	565	497 502	492 592
Final weight	1025	903.2	1011	946	815 848	860 878
Final score					Dec. Mar.	Dec. Mar.
Cond.	Low Ch.	Low Ch.	4 Good	6 Ch.	5 Ch. 4 Ch.	4 Ch. 3 Ch.
Conf.	7.64			3 Good		1Gd. 2Gd.

* 84 days reported here. Third 4-week period omitted from gain and efficiency figures.

COLORADO STATE UNIVERSITY

- I. Station: Colorado Agricultural Experiment Station, Fort Collins, Colorado
- II. Project Title: Improvement of beef cattle through breeding. A study of inbreeding and the crossing of inbred lines within the Hereford breed
- III. Personnel:
- Experiment Station:
- H. H. Stonaker, Kent Riddle, T. R. Blackburn, Ellen Norris, Laura Ann Harris, Beverly Bray, Donald Moore, Dudley Campbell, and A. B. Canterbury.
- U. S. Department of Agriculture
- R. T. Clark, Coordinator
- C. E. Shelby

IV.V. Nature and Extent of Work Done This Year, and Summary of Progress and Conclusions to Date:

Rates of gain of 414 Hereford bulls as affected by inbreeding, line, age, weight, years, and pens were analyzed by Donald Moore (1958). A linear model was set up in which the constants evolved by iterative solutions of simultaneous equations were for 9 years, 5 inbreeding levels, 13 sire lines, and initial age and initial weight. These values were found:

$$\mu = 2.16$$

$$\text{Years: } Y_1 = +.40, Y_2 = +.19, Y_3 = -.41, Y_4 = +.17, Y_5 = +.00, Y_6 = -.22, Y_7 = +.05, Y_8 = +.09, Y_9 = -.33$$

$$\text{Inbreeding: } F_{.0-.09} = -.006, F_{.10-.19} = +.00, F_{.20-.29} = .002, \\ F_{.30-.39} = -.03, F_{.40-} = -.03$$

$$\text{Effect of day of age} = -.003$$

$$\text{Effect of one pound initial weight} = +.003.$$

The significance of these effects has not been computed at this time, but year effects on daily gain seem great and indicate caution in between-year comparison in this trait. Inbreeding effects seem small and variable in effects. There seemed slight advantages in daily gains from young initial ages and greater initial weights. The deviations due to 13 sire lines seemed great, ranging from -.35 to +.21 for extremes.

Estimating breeding soundness of yearling Hereford bulls. Semen samples were taken from 221 yearling bulls by means of the Marden electro-ejaculator. The semen was graded for motility, concentration, morphology, and viability by Drs. Scott and Faulkner. In addition, the bulls were observed for anatomical or other defects which might affect their predicted breeding soundness. Significant differences were found in estimated breeding soundness of bulls produced by different mating systems. For example, 66 percent of the inbreds, 30 percent of the linecrosses, and 64 percent of the bulls belonging to cooperators were classed as satisfactory, others being questionable or unsatisfactory. Differences between lines were observed but not significant. Generally, scores for semen quality paralleled the satisfactory, questionable, and unsatisfactory categories.

Cow Production of Linecrosses. Preliminary data indicate that the different linecross cow groups greatly affect total calf production measured by the product of the calf crop and weaning weights. Pounds of calf per cow exposed range from 217 to 394 pounds, with group differences of 30 to 60 pounds of calf per cow being commonly found.

Progeny testing sires from various lines. Cooperative tests continue with the California and Mississippi stations. No results are evident yet from the Mississippi station. The first calf crop has been weaned and fed out using the first California Rover line bull at Fort Lewis. Linecross cows were assorted at random within age group to the Rover, Brae Arden, and San Juan bulls. Results on adjusted weaning weights of the first calf crop were as follows for divided cow groups:

Sires	Rover		Brae Arden		San Juan		Bonanza	
Cow Groups	No.	Wean Wt.	No.	Wean Wt.	No.	Wean Wt.	No.	Wean Wt.
San Juan	3	443	3	518				
La Plata	4	462	1	440				
Brae Arden	4	458			5	467		
Don	4	403					4	465

For all linecross groups in 1957, without considering differences in cow groups, daily gain and adjusted weaning weights were as follows:

Sire Line	No. Calves	Adjusted Wean. Wt.	No.	Daily Gain
Brae Arden	12	476	4	2.73
San Juan	16	428	9	2.40
Bonanza	9	442	5	2.37
Don	8	434	3	2.13
Colorado	9	420	5	2.06
Monarch	6	445	4	2.36
Rover	15	442	7	2.11
Control	8	420	3	2.15

VI. Work Planned for the Future:

200 cows on the Coddling Ranch, Foraker, Oklahoma, were allotted at random to 10 herd bulls from Fort Lewis. Weaning and feed-lot data should be obtainable from the steer calves in 1959-60. It is hoped that this may be continued. Expansion in testing facilities is sorely needed.

VII. Publications and Manuscripts:

Colorado Agricultural Experiment Station. 1958. Beef Cattle Improvement Day, May 31. General Series 683.

Harris, Laura A., L. C. Faulkner, and H. H. Stonaker. 1958. The effect of inbreeding on the estimated breeding soundness of yearling Hereford bulls. Amer. Soc. Anim. Prod. West. Sect. Proc. 9: .

Lindholm, H. B., and H. H. Stonaker. 1957. Economic importance of traits and selection indexes for beef cattle. J. Anim. Sci. 16(4):998-1006.

Moor, D. B., H. H. Stonaker, and Kent Riddle. 1958. Rates of gain in Hereford bulls as affected by inbreeding, line, age, weight, years, and pens. Amer. Soc. Anim. Prod. West. Sect. Proc. 9: .

Stonaker, H. H. 1958. Breeding for beef. Colo. Agr. Expt. Sta. Tech. B. 66. (In press.)

Cattle Inventory
Purebreds

PROJECT SUMMARY
Colorado Agricultural Experiment Station

Breed	Hereford									
Line	(Verde) Animas	Bonanza	Brae Arden	Colorado	Don	Fort Lewis*	LaPlata*	Mesa*	Rover	Model Domingo
Station Bulls (12 mos. or over)	San Juan	Basin Experiment Station, Hesperus, Colorado								
Cows (2 yrs. or over)	12	0 + 6	1 + 7	1 + 6	1 + 6	-	-	-	3-7	-
Heifers, yearlings	-	13	27	14	20	7	6	3	-	5
Bull calves	1	2	1	2	1	-	-	-	-	-
Heifer calves	1	5	11	3	0	-	-	-	-	1
Percentage used for breeding project	1	7	8	1	-	-	-	-	-	1
Estimated cash value	100	100	100	100	100	100	100	100	100	100

* On lease.

Breed	Hereford									
Line	Monarch	Prospector	Royal	San Juan	Real Prince	Tar- ington	Control	Crossbred Controls	On Lease	Un- known
Station Bulls (12 mos. or over)	1-7	1-5	1-2	1 + 11	1-1	1-0	1-3	-	6	
Cows (2 yrs. or over)	17	13	14	21	10	8	13	9	20	
Heifers, yearlings	1	1	1	1	0	1	0	0	55	
Bull calves	9	8	7	10	4	7	6	3		6
Heifer calves	10	13	7	7	3	6	6	3		2
Percentage used for breeding project	100	100	100	100	100	100	100	100		
Estimated cash value										

Young Animals on Feed Purebreds Colorado Agricultural Experiment Station

	Hereford		Angus
	Number Individually fed	Number group fed	Number individually fed
Bulls	96	Leased Feb. 1958 39 (1957-58)	3
Heifers			
Steers			

Land, Physical Facilities, and Equipment Used

Item	Number	Actual Cash Value	Percentage used for breeding project
6,000 acres range		\$20,000	100
Sheds, corrals, feeders, scales, granaries, etc.		20,000	100
Equipment		5,000	100

Cow Production Data*

Colorado Agricultural Experiment Station

Breed Line-Inbreds and Crossbreds	Hereford			Hereford			Hereford			Hereford		
	Bonanza 13			Brae Arden 24			Colorado 12			Don 22		
Cows bred												
Calves born												
Alive	7			17			10			19		
Dead	2			3			2			0		
Total	9			20			12			19		
Calves weaned	7			17			10			17		
% calf crop												
Birth	69.2			83.3			100.0			86.4		
Weaning	53.8			70.8			75.0			77.3		
Average	Bulls		Steers		Heifers		Bulls		Steers		Heifers	
	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.
Birth weight	4		3		6		11		2		8	
Weaning age	192		202		204		196		201		202	
Weaning weight	334		397		441		390		458		390	
Adj. weaning wt. - 200 days**	393		496		494		486		542		467	
Weaning score	-		-		-		-		-		-	
Cond.	-		-		-		-		-		-	
Conf.	-		-		-		-		-		-	

* 1957 calves.
** Includes adjustment for inbreeding.

Breed	Hereford			Hereford			Hereford			Hereford		
Line	Monarch			Prospector			Royal			San Juan		
Cows bred	18			13			13			20		
Calves born												
Alive	15			12			11			13		
Dead	1			0			1			3		
Total	16			12			12			16		
Calves weaned	14			11			11			11		
% calf crop												
Birth	88.9			92.3			92.3			80.9		
Weaning	77.8			84.6			84.6			55.0		
Average												
Birth weight	Bulls No. Av.	7	Heifers No. Av.	7	5	7	Bulls No. Av.	4	Heifers No. Av.	3	Steers No. Av.	8
Weaning age	187		210	199	210	198	220	213	220	198		198
Weaning weight	379		373	437	435	411	482	431	482	422		422
Adj. weaning wt. - 200 days	449		418	501	460	462	508	470	508	482		482
Weaning score												
Cond.	-	-	-	-	-	-	-	-	-	-	-	-
Conf.	-	-	-	-	-	-	-	-	-	-	-	-

* 1957 calves.

Colorado Agricultural Experiment Station

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See General Series paper No. 683 for details of 1957 feed test.

Phenotypic classification of calves by profile type and by breeding tests of sires and dams, 1953, 1954, 1955, 1956, are in the 1957 Report. 1958 calving records are incomplete at this time.

UNIVERSITY OF HAWAII

I. Station: Hawaii Agricultural Experiment Station, Honolulu, Territory of Hawaii

II. Project Title: The improvement of beef cattle through the application of breeding methods

III. Personnel:

Experiment Station:

Estel H. Cobb, and Oliver Wayman.

Cooperators:

Parker Ranch, Kukaiau Ranch, Kapapala Ranch, and Kaalualu Ranch

U. S. Department of Agriculture:

R. T. Clark, Coordinator

C. E. Shelby

IV. and V. Nature and Extent of Work Done This Year, and Summary of Progress and Conclusions to Date:

The collection of routine data at weaning, 12 months, and 20 months of age has continued. Cooperation with Parker Ranch and Kukaiau Ranch was terminated after the weights and grades at 20 months of age were taken on the 1956 calf crop. Work with Kapapala Ranch and Kaalualu Ranch has continued. Arrangements have been made starting this year to expand the program to include lifetime records on the females and carcass information on samples of the progeny from each of the sire groups.

Analysis of the first five years' data has been emphasized. All of the records have been transferred to IBM cards and are being summarized. Correction factors for the effects of sex, age of dam, and age at weaning on weaning weight will be obtained. In addition, heritability estimates for weaning weight and grades, 12-month weight and grade, and 20-month weight and grade will be obtained.

Considerable interest in the program on the part of the ranchers is evidenced by the fact that several, in cooperation with the Extension Service, have started or are planning record of performance programs of their own.

VI. Work Planned for the Future:

The analysis of the first five years' data will be emphasized. The results will be written up in a station bulletin.

The project outline is being revised and will be circulated in the near future.

The collection of weaning, 12-month, and 20-month data will continue. More detailed records of cow performance are planned. Samples of each sire's progeny will be fattened on grass and slaughtered for carcass information. Reciprocal crosses between cattle on the two ranches have been made to test the mothering ability and to see how the two strains will perform when crossed.

Plans are being developed to put the records on IBM cards as they are collected.

VII. Publications and Manuscripts:

None.

Cattle Inventory Purebreds

PROJECT SUMMARY Hawaii Agricultural Experiment Station

Breed	Hereford	Hereford
Line		
Station	Kaalualu	Kapapala
Bulls (12 mos. or over)	3	3
Cows (2 yrs. or over)		
Heifers, yearlings		
Bull calves		
Heifer calves		
Percentage used for breeding project	100	100
Estimated cash value	\$5,600	\$2,900
Grades		
Breed	Hereford	Hereford
Line	D	E
Station	Kaalualu	Kapapala
Bulls (12 mos. or over)	17	10
Cows (2 yrs. or over)	260	120
Male calves	28	27
Heifer calves	79	31
Percentage used for breeding project	100	100
Estimated cash value	\$62,760	\$31,390

Young Animals on Feed None.

Hawaii Agricultural Experiment Station

Land, Physical Facilities and Equipment Used

Item	Number	Actual Cash Value	Percentage Used for Breeding Project
D. Land (acres)	1,150	\$12,600.00	100% Annual lease value
Corrals and Chutes	1 set	2,400.00	100%
Portable scale	1	650.00	80%
E. Land (acres)	924	10,123.00	100% Annual lease value
Corrals, chute, scale	1 set	3,300.00	100%
University of Hawaii Portable scale	1	720.00	100%
Profilometer	1 set	200.00	100%
Leica camera set	1	613.10	50%
Electronic ejaculator	1	543.74	100%
Monroe adding machine	1	238.18	65%
Friden calculator	1	658.75	80%
Total		32,046.77	

Cow Production Data Hawaii Agricultural Experiment Station

Breed	Hereford	Hereford
Line	Kaalualu	Kapapala
Cows bred	252	90
Calves born		
Alive	171	65
Dead		
Total	171	65
Calves weaned	164	62
% calf crop		
Birth	68	72
Weaning	65	68

	Bulls	Steers	Heifers	Bulls	Steers	Heifers
	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.	No. Av.
Average Birth weight						
Weaning age	250		244	235		236
Weaning weight	75 472		89 432	34 542		28 501
Adj. weaning wt.-180 days	75 466		89 427	34 558		28 513
Weaning score						
Cond.	- -		- -	- -		- -
Conf.	75 3.2*		89 3.9*	34 4.6*		28 5.4*

* 9 = top grade and 1 = bottom grade.

Feed Lot Performance None.

UNIVERSITY OF IDAHO

I. Station: Idaho Agricultural Experiment Station, Moscow, Idaho

II. Project Title: The improvement of beef cattle through:
(1) linebreeding within the Hereford and Shorthorn breeds,
(2) testing linebred sires within the various lines which will be developed, and (3) determining the relative importance of various reproductive phenomena.

III. Personnel:

Experiment Station:

R. E. Christian, C. W. Hodgson, T. D. Bell, and
S. E. Slyter

U. S. Department of Agriculture:

R. T. Clark, Coordinator
C. E. Shelby

IV. Nature and Extent of Work Done This Year:

Performance and production data have been collected according to the project outline. The 1957 calves were weaned at approximately 150 days of age due to the poor pasture conditions, and for this reason the weaning weights were not as large as those of the previous year. Twelve bull calves (7 Hereford, 3 Shorthorn and 2 Angus) were individually fed for 140 days to obtain feed-lot performance. One Hereford bull was removed from the test because of bloat. Each animal was fed daily approximately 1-1/2 pounds of concentrate mix per 100 pounds of body weight plus all the alfalfa-grass hay he would eat. The concentrate mix was composed of the following: rolled oats, 44 percent; rolled barley, 34 percent, beet pulp, 15 percent; linseed oil meal, 5 percent; salt, 2 percent.

The average rate of daily gain was 1.96 lbs. for the Hereford bulls, 1.39 lbs. for the Shorthorn bulls, and 1.85 lbs. for the Angus bulls. The Hereford bulls required 444.0 lbs. of concentrate and 286.1 lbs. of hay per 100 lbs. of gain, the Shorthorns required 445.1 lbs. of concentrate and 302.0 lbs. of hay per 100 lbs. of gain, and the Angus required 407.9 lbs. of concentrate and 282.6 lbs. of hay per 100 lbs. of gain.

The study on age at puberty in the beef heifer was continued with the heifers from the 1957 calf crop. Twice daily heat checks were made with a vasectomized bull beginning when the heifers were approximately 7 months of age. Rectal palpations were made at weekly intervals to determine the extent of ovarian activity prior to puberty and also to determine if ovulation occurred at first estrus.

The average age at puberty was 373.5 days for the 13 Hereford heifers, 374.6 days for the 9 Shorthorn heifers, and 392.3 days for the 6 Angus heifers. When the data for the two years are combined, the average age at puberty is 376 days for 29 Hereford, 379.1 days for 19 Shorthorns, and 369.2 days for 15 Angus. Three animals (one Shorthorn and two Hereford) apparently did not ovulate at first estrus. The two Hereford each had a cystic follicle (20 mm. and 26 mm. in diameter, respectively) when palpated approximately one week after estrus. These two animals returned in heat in 17 and 20 days, respectively, and both ovulated at second heat. The Shorthorn had ovaries with no palpable follicle or corpus luteum following first estrus. This animal returned to heat in 18 days and ovulated.

As with last year, there was considerable follicular development prior to puberty in most heifers. Eighteen of the heifers ovulated at least once prior to first detected estrus. Of these animals, 6 ovulated twice and 2 ovulated three times each prior to puberty. Four of the heifers had follicles 15 mm. or larger prior to puberty. Most of the others had follicles 10 - 14 mm. in diameter prior to first heat.

It is not possible to date to determine to what extent age at puberty is heritable since only 10 cows had heifer calves both years. The study will be continued with the females from the 1958 calf crop.

All Hereford cows have been palpated per rectum following parturition to determine the length of the interval from calving to involution of the uterus and to first ovulation. The average interval from parturition to involution of the uterus in 38 Hereford cows was 41.3 days and to first ovulation was 44.2 days. This study is being continued.

Ten additional Hereford cows known to be heterozygous for the gene for dwarfism were purchased this past year for use in progeny testing our herd bulls. They also are being used in studies to detect animals heterozygous for the gene for dwarfism. These studies are just getting under way.

V. Summary of Progress and Conclusions to Date:

The first two years' work on age at puberty in the beef heifer would indicate that there is considerable yearly variation but that there is relatively less difference between breeds. The beef heifer first comes in heat at approximately one year of age. Most heifers ovulate at first heat.

Some heifers do not come in heat until at least 15 months of age, which may be one cause for a lower percentage calf crop from heifers bred to calve at two years of age.

The beef cow requires approximately 6 weeks for the uterus to return to normal size, position, and tone following calving. The first post-partum ovulation also occurs at approximately 6 weeks. This would indicate that beef cows probably should not be rebred before that time.

VI. Work Planned for the Future:

The study on age at puberty in the beef heifers will be continued with the 1958 heifer calves. The study on interval from calving to involution of the uterus and to first ovulation will be continued to determine if either of these phenomena are related to subsequent reproductive performance. Additional reproduction studies will be initiated as facilities and animals become available.

VII. Publications and Manuscripts: None.

Cattle Inventory PROJECT SUMMARY Purebreds Idaho Agricultural Experiment Station

Breed	Hereford	Shorthorn	Angus
Station	Main	Main	Main
Bulls (12 mos. or over)	10	4	4
Cows (2 yrs. or over)	56	23	27
Heifers, yearlings	16	9	6
Bull calves	21	9	12
Heifer calves	17	9	9
Percentage used for breeding project	75	75	75
Estimated cash value	\$30,900	\$12,750	\$15,000

Young Animals on Feed Purebreds

	Hereford		Shorthorn		Angus	
	No. ind. fed	No. group fed	No. ind. fed	No. group fed	No. ind. fed	No. group fed
Bulls	7	0	3	0	2	0
Heifers	0	13	0	9	0	6
Steers	0	5	0	4	0	0

Item	Number	Actual Cash Value	Percentage Used for Breeding Project
Microscope	1	\$775	50
Corrals		400	75
Calculator	1	300	50
Portable scale	1	750	25

[illegible]

Feed Lot Performance Idaho Agricultural Experiment Station

Breed	Hereford	Shorthorn	Angus
Sex	Bulls	Bulls	Bulls
Number on test	6	3	2
Average			
Age on test	251.7	258.3	232.0
Initial weight	534.7	495.3	449.5
Initial score			
Conf.	4.7	5.3	4.5
Days on test	140	140	140
Gain			
Total	274.7	264.7	259.0
Average	1.96	1.39	1.85
Efficiency of			
feed utilization			
# TDN/100# gain	467.2	476.0	439.0
Final weight	808.3	760.0	708.5
Final score			
Conf.	4.8	5.0	5.0

MONTANA STATE COLLEGE

- I. Station: Montana Agricultural Experiment Station, Bozeman, Montana, and the North Montana Branch Station, Havre, Montana
- II. Project Title: Recurrent selection and record of performance selection in open and closed beef cattle herds
 - A.
 1. The establishment of inbred lines of registered Hereford cattle, both horned and polled, that will result in improvement in such characters as rate and economy of gain, fertility, nursing ability, longevity, and carcass quality.
 2. The maintenance of an outbred herd of Herefords with bulls selected and furnished by the purebred breeders. The bulls are to be primarily good, high-scoring individuals according to breed association standards.
 - B.
 1. The establishment of an improved herd of registered Angus cattle in which the males are selected on a high level of performance as indicated by standard record of performance procedures.
 - C.
 1. The investigation of the feasibility of breeding for specific combining ability through recurrent selection.
- III. Personnel:
 - Experiment Station:
 - F. S. Willson, A. E. Flower, E. P. Orcutt, Bozeman
 - J. J. Urick, North Montana Branch Station, Havre
 - Claude Windecker, North Montana Branch Station, Havre
 - U. S. Department of Agriculture:
 - J. R. Quesenberry, U. S. Range Livestock Experiment Station, Miles City
 - R. T. Clark, Coordinator
 - C. E. Shelby

IV. Nature and Extent of Work Done This Year:

Bozeman

This year, the feeding trials with bulls were relatively uneventful. Postweaning "warmup" gains continued to favor the Angus somewhat, but Herefords were reasonably comparable. It may be presumed that some unidentified pre-weaning treatment may have influenced last year's erratic Hereford "warmup" gains.

The 12-month corrected weight was figured on a linear basis to weaning; warmup gains were added, and actual days over or under 365 days were corrected using daily gain on feed as a correction factor (see table 1).

To make records somewhat comparable among years as well as increase accuracy within years, the yearling weight and bull grade were placed at 25-lb. and 2-point intervals, respectively, before applying the weighting factor. Since it is impossible to decide accurately how much weighting to place on weight for age and for grade, the arbitrary figure of 60 for 12 months corrected weight and 40 for yearling grade was assigned. It is hoped that a constant weighting of these factors will continue to be applied sufficiently long to enable us to observe results in those herds which are closed.

Table 1 gives a summary of the bull indexing report; however, it does not summarize by sire groups. We are continuing our cooperation with the Montana Hereford Association and the Montana Angus Association since their committees were active again in selecting a show type bull of each breed to be used on what is termed our "show type" cow herd of each breed. The bulls in the respective R.O.P. herds were the same as were used the previous year. The average daily gain varied from 2.2 to 2.8 pounds (see table 1). There was only one show type Hereford bull to be indexed. In the over-all weighted combined score, he ranked number 3 even though he tied with one of the R.O.P. bulls in average daily gain. The show type bull's visual appraisal was a score of 80, whereas the average of the eight R.O.P. bulls was 75. There were five show type Hereford heifers and five R.O.P. heifers fed this winter. The show type heifers' appearance was a little better with a score of 81 against an average score of 75 for the R.O.P. heifers. The average daily gain was superior for the R.O.P. heifers by about .3 pound per day.

A year ago, two of our show type bulls were bred on a test herd at Miles City. The calves will be compared this fall and winter with other lines at the Miles City station. We also sent two R.O.P. bulls to Miles City this year to be test bred.

The Montana Angus Association selected a very showy bull last year from Mrs. Sam Lee to use on our show type herd. This bull was about 350 pounds lighter than our bulls of comparable age. The calves arriving this year are much smaller than our R.O.P. calves. We lost one of our yearling Angus bulls just before the end of the indexing, so we had only four complete the indexing test. The R.O.P. bulls gained about a quarter of a pound more than the show type bulls per day and they also scored higher with a score of 85, which is about 8 points higher than the average of the show type bulls.

There were eight R.O.P. Angus heifers and three show type heifers wintered. The R.O.P. heifers gained about .2 pound more than the show type heifers. The R.O.P. heifers scored an average of 77 as compared with 75 for the show type.

The Montana Hereford Association, as well as the Montana Angus Association, committees have selected bulls for use this year that are as large as our R.O.P. bulls in weight for age. We have bought the show type bull selected by the Hereford Association and are in the process of buying the show type Angus bull selected by their association. This is in line with the recommendations by the respective associations.

A year ago last winter we brought 46 crossline three- and four-year-old cows from the Havre station to our Red Bluff Ranch, 32 miles west of Bozeman. We also bought 16 cows of similar age from two good commercial producers and placed them on the Red Bluff Ranch. It was interesting to note the difference in the performance of the crossline cows as compared to the outbred commercial cows. The 180-day corrected weaning weight was about 33 pounds in favor of the three-line cross calves. The score on these crossline calves was also about 2 points higher. Of course, there are differences in sire effects in this particular crop of calves; however, the crop of calves that is arriving this spring will be all sired by the same group of indexed sires, so our comparison next fall should give us only crossline effect of dam.

Havre

At the Havre station, the recurrent selection trials with the Hereford cattle are being continued. This is the sixth year for this project. During the past winter, 53 head of steer calves were fattened on a standard grain and hay ration. The steers in this feeding trial included a Miles City Line 1 group (controls), six crossline groups involving two sires from each of three purebred lines top crossed on grade cows mainly of Miles City Line 1 breeding. The grade cows were randomly selected for each sire used. Fifteen of the steers were from crossline heifers mated to an unrelated third line.

From the feeding results this year (196 days), there appeared to be an advantage for four of the crossline groups of steers in daily gain and final weight over the control steers. One group of crossline steers was below the control group in gain and another group about the same. All of the sire groups were randomized in various lots, which would tend to eliminate lot effect.

The performance of the steers from the three line cross matings seemed to be about the same as the two line cross steers. However, there were too few animals in this trial this year to make accurate observations.

A slight change in the grain ration this year should be mentioned in that the barley was steamed rolled rather than dry rolled. The steamed barley seemed to eliminate the occurrence of bloat which had been a problem. A slight increase in gain this year over previous years might be attributed to the elimination of the bloat problem in this area when feeding barley and alfalfa in combination.

All of the heifer calves were wintered outside on an alfalfa hay ration fed ad libitum. The crossline heifers gained about the same as the grade control heifers. The purebred heifers seemed to be less thrifty during the winter and were noticeably lighter in weight at the completion of the winter trial.

During the past year, 20 head of purebred bulls from three lines of Hereford cattle were fed individually for a period of 168 days. The daily gains ranged from a high of 2.65 to a low of 2.00 pounds. Two top bulls from each of three lines were selected for test herd matings this summer on grade cows. A three-man scoring committee from the Montana State College Extension and Animal Industry Department, graded the bulls at the completion of the feeding trial. The grades ranged from top range bull category of 2 plus to a low of 3 plus which would be considered a reject. Some bulls in the closed lines showed noticeable weakness in the hind legs. Surplus bulls that were desirable from the standpoint of grade and gain were sold to commercial breeders in this area. Rejects were sold for slaughter.

V. Summary of Progress and Conclusions to Date:

Bozeman

The interest of the feed industry seems to be increasing as a result of the publicity of the Extension Service and with the organization of our Beef Cattle Performance Registry Association. Our state association will certify over 1,000 commercial calves for sale this fall, all sired by bulls with better than an average gain index. They also have over 1,100 purebred bulls and heifers in their program. This association has been in operation over a year and a half and is gaining rapidly in membership. Mr. F. S. Willson is on the Board of Directors and at the present time Mr. E. P. Orcutt, Extension Livestock Specialist, is their Secretary.

Two of the members of this association received premiums of at least 6 cents per pound for commercial calves from their certified indexed bulls for delivery this fall. These calves were contracted at 37 cents. This kind of publicity will certainly do a lot to sell the performance testing program to the beef cattle industry.

Table 1. Bull index (Bozeman) 1957-58 Montana Agricultural Experiment Station

Calf Ear tag (No.)	Cow Ear tag (No.)	Cow Age (Yrs.)	Birth Weight (Lbs.)	180-Day Weight Corrected for Age and Age of Dam (Lbs.)	Actual Weaning Weight (Lbs.)	Pre-weaning Average Daily Gain (Lbs.)	Warmup Gain, 32 Days (Lbs.)	Weight on Feed (Lbs.)	Weight Off Feed (Lbs.)	Gain on Feed (Lbs.)	140-Day Average Daily Gain (Lbs.)	12-Month Corrected Weight (Lbs.)	12-Month-Weight Score in 25-Pound Intervals	*Yearling Bull Grade	Grade Score in Intervals of 2 Points	**Yearling Index Relative 60-40 Basis	Weighted Combined Score Rank	Sire
Hereford																		
H540	208	8	83	370	440	1.59	66	506	904	398	2.84	871	6	80	9	7.2	3	1
H544	179	9	82	409	430	1.70	34	464	813	349	2.59	826	5	67	2	3.8	8	2
H546	411	6	67	385	425	1.76	54	479	790	311	2.22	779	3	82	10	5.8	6	2
H547	729	3	67	424	440	1.87	53	493	838	345	2.56	855	6	77	7	6.4	4	2
H551	180	9	80	477	480	2.07	38	518	855	337	2.40	883	7	80	9	7.8	2	2
H555	303	7	72	453	470	2.11	42	512	905	393	2.80	924	9	82	10	9.4	1	2
H565	817	2	75	377	330	1.50	34	364	720	356	2.54	800	4	72	5	4.4	7	2
H566	408	6	75	449	430	2.07	12	442	798	356	2.54	850	6	75	6	6.0	5	2
H553	818	2	70	343	325	1.34	38	363	675	312	2.22	722	1	64	1	1.0	6	2
Angus																		
A446	3	10	67	495	410	2.13	46	456	765	309	2.20	879	3	75	1	2.2	4	3
A442	20	5	70	445	435	2.08	65	500	805	305	2.17	843	1	79	3	1.8	2	3
A435	19	6	80	504	565	2.35	53	618	955	337	2.40	925	5	85	9	5.4	1	4
A432	13	5	55	424	500	2.05	63	563	871	308	2.20	824	1	78	2	1.4	3	5

* A.H. Form 522, U.S.D.A.

** Weighted - 60% yearling weight, 40% yearling grade.

Sire Key: Hereford

1. Mischief D. P. Lad 8666926
2. M.S.C. Clay D. Supreme 8991837

Sire Key: Angus

3. Elan of Burns 1969529
4. M.S.C. Bataans Restorer 2 1921764
5. M.S.C. Bataans General 50 2129183

Havre

From six years' results so far at the Havre station it appears that the steers from the crossline matings where the bulls from the Havre purebred lines are crossed with the grade cows mainly of the Miles City Line 1 background, have shown some advantage in daily gain over the controls which have been selected on gaining ability over a period of 20 years. From the results to date it seems that the commercial cattleman seeking good feed-lot cattle will gain some hybrid vigor by using bulls from closed lines of proven performing ability.

One of the station linebred bulls will be used by a local rancher this year with a group of his cows to obtain additional information on performance of subsequent calf progeny as compared to calves from the conventional program he now has in operation. A number of ranchers have expressed interest in a similar cooperating program as soon as scale facilities are available on their places. Several groups of steers from top commercial herds in this area will be fed out starting this fall in comparison with the station calves for a test of feed-lot performance.

VI. Work Planned for the Future:

Bozeman

We are not contemplating any great change in our program. We hope that in another year it will be possible to test-breed one bull at least out of our show type and R.O.P. Hereford herds. In the future, increased emphasis will be placed on the importance of heredity in carcass traits and how to relate them to live animal appearance. We have developed a color photo grid device which is rather small and handy to be used in taking measurements of rib-eye muscles on carcasses. This is somewhat similar to the device used for photographing cancer eye in cattle.

Havre

In the future, more emphasis will be placed on getting cooperating ranchers to use performance testing procedures in their herds of commercial and purebred cattle. The testing of outbred steers from commercial herds at the station against steers of the recurrent selection project should be of considerable interest to both station and commercial people. An attempt will be made to place all surplus crossline heifers with cooperating ranchers for obtaining additional information on weaning weight performance of various crossline cows vs. commercial outbred cows.

VII. Publications and Manuscripts:

Flower, A. E. 1957. Review of some important considerations in beef cattle reproductive performance. Mont. State Col. Third Annual Beef Production School Proc. December 1957.

Orcutt, E. P. 1957. What is an I. P. R. bull? Mont. State Col.

PROJECT SUMMARY

Montana Agricultural Experiment Station

Montana Agricultural Experiment Station

Bozeman

-52-

Havre

Red Bluff Ranch, Norris

Breed	Hereford	Line	Tester HL4				
Bulls (12 mos. or over)	1					3 (Purebred)	\$550
Cows (2 yrs. or over)	130					63	\$150
Male calves	55					29	75
Heifer calves	78					25	75
Percentage used for breeding project	90					20	
Estimated cash value	\$16,450						\$15,150

Young Animals on Feed
Purebreds

Montana Agricultural Experiment Station

Bozeman

	Hereford		Angus	
	Number individually fed	Number group fed	Number individually fed	Number group fed
Bulls	9	-	4	-
Heifers	-	10	-	11
Steers	-	6	-	-
Grades	Havre		Bozeman	
Bulls	19	-	-	-
Heifers	-	18	-	5
Steers	-	-	-	3

Land, Physical Facilities, and Equipment Used

Bozeman

Item	Number	Actual Cash Value	Percentage Used for Breeding Project
Beef barn and corrals	1	\$ 20,000.00	60
Sheds	4	5,000.00	60
Irrigated land	200 acres	30,000.00	100
Saddle horses	2	300.00	60
Miscellaneous equipment		700.00	60
Total		\$106,000.00	

Red Bluff Ranch, Norris, Montana

Houses	4	\$ 20,000.00	10
Old sheds, corrals	3	2,000.00	10
New shed	3	2,000.00	10
Deeded grazing land	9,906 at \$12.75	124,153.00	10
Irrigated land	273 at \$70.00	19,110.00	10
Saddle horses	1	150.00	10
Total		\$168,013.00	

Havre

Bull barn	1	\$ 18,000.00	90
Long shed	1	18,000.00	90
Home pasture	1,780 acres	28,700.00	100
Home farm land	200 acres	6,000.00	85
Leased pasture	5,000 acres	55,000.00	100
A.I. truck	1	2,000.00	80
Saddle horses	7	700.00	100
Scale & weigh house(home)	1	1,900.00	90
Scale & weigh house(mts.)	1	500.00	100
Corrals (home)		3,000.00	90
Corrals (mts.)		15,000.00	100
Cattle squeeze	2	400.00	100
Cabins (mts.)	2	2,000.00	100
Automatic waterers	5	500.00	90

Cow Production Data* North Montana Branch Station, Havre, Montana

Breed	Hereford		Polled Hereford	
Line	Grades		Line 1	
Cows bred	130		19	
Calves born				
Alive	117		15	
Dead	5		1	
Total	122		16	
Calves weaned	121		15	
% calf crop				
Birth	94		84	
Weaning	90		80	
	Bulls		Heifers	
	No.	Av.	No.	Av.
Average				
Birth weight	-79	74	78	71
Weaning age	189	183	193	187
Weaning weight	415	374	382	346
Adj. weaning wt. - 180 days	400	369	360	333
Weaning score				
Cond.	79	79	73	74
Conf.	79	79	73	74

* 1957 calves

Cow Production Data* North Montana Branch Station, Havre, Montana

Breed	Horned Hereford		Horned Hereford	
Line	Line 2		Line 3	
Cows bred	30		13	
Calves born				
Alive	25		14	
Dead			2	
Total	25		16	
Calves weaned	25		14	
% calf crop				
Birth	83		89	
Weaning	83		78	

	Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average								
Birth weight	77		75		77		74	
Weaning age	175		181		180		187	
Weaning weight	352		366		345		378	
Adj. weaning wt. - 180 days	361		364		345		365	
Weaning score								
Cond.	76		78		77		78	
Conf.	76		78		77		78	

* 1957 calves

Cow Production Data* Montana Agricultural Experiment Station

Bozeman

Breed	Hereford			Hereford		
Line	A. Linebred R.O.P.			B. Show Type		
Cows bred	19			17		
Calves born						
Alive	19			16		
Dead	1			1		
Total	20			17		
Calves weaned	19			15		
% calf crop						
Birth	105.0			100.0		
Weaning	100.0			88.0		
	</					

* 1957 calves, bred to calve at two years of age

** A. H. Form 522, U.S.D.A.

Cow Production Data* Montana Agricultural Experiment Station
Bozeman

Breed	Angus			Angus		
Line	C. R.O.P.			D. Show Type		
Cows bred	14			12		
Calves born						
Alive	14			8		
Dead	0			0		
Total	14			8		
Calves weaned	13			7		
% calf crop						
Birth	100.0			67.0		
Weaning	93.0			58.0		

	Bulls		Steers		Heifers		Bulls		Steers		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average												
Birth weight	(2)	67.5	-	-	(11)	62.5	(4)	68.0			(3)	58.0
Weaning age		211.5				197		154.5				183.7
Weaning weight		500				380.4		341.2				368
Adj. weaning												
wt. - 130 days		464				376.7		414.5				394
Cor. and age of dam												
Weaning score												
Cond.												
Conf.**		85.5				76.3		74.4				79.4

* 1957 calves, bred to calve at two years of age

** A. H. Form 522, U.S.D.A.

Cow Production Data* Red Bluff Ranch, Norris, Montana

Breed	Hereford		Hereford	
Line	Crossline cows		Out cross cows	
Cows bred	46		16	
Calves born				
Alive	36		13	
Dead	0		0	
Total	36		13	
Calves weaned	34		12	
% calf crop				
Birth	78.2		81.2	
Weaning	73.9		75.0	
	Steers	Heifers	Steers	Heifers
	No. Av.	No. Av.	No. Av.	No. Av.
Average				
Birth weight	76.6	73	69.5	74.5
Weaning age	183	199.3	180	189
Weaning weight	375.6	394	326	347.5
Adj. weaning				
wt. - 180 days	362.5	361	327	332
Weaning score				
Cond.				
Conf.**	82.0	82.7	79.4	81.1

* 1957 calves

** A. H. Form 522, U.S.D.A.

Montana Agricultural Experiment Station

Feed Lot Performance (Havre--Steers R.O.P. 196 days)

Breed	Hereford	Hereford	Hereford
Line	MC 1	HL 1 x MC 1	HL 1 x MC 1
Sex	Steer	Steer	Steer
Number on test	7	4	5
Average Age on test	199	201	195
Initial weight	429	419	419
Initial score			
Cond.	79	77	81
Conf.	79	77	81
Days on test	196	196	196
Gain			
Total	438	479	447
Average	2.23	2.44	2.28
Efficiency of feed utilization #TDN/100# gain or #Gain/100# TDN			
Final weight	867	898	866
Final score			
Cond.	-	-	-
Conf.	-	-	-

Montana Agricultural Experiment Station

Feed Lot Performance (Havre--Steers R.O.P. 196 days)

Breed	Hereford	Hereford	Hereford	Hereford
Line	HL 2 xMC1	HL 2 xMC 1	HL 3 xMC 1	HL 3 xMC 1
Sex	Steer	Steer	Steer	Steer
Number on test	4	6	7	5
Average Age on test	188	186	202	199
Initial weight	423	402	447	422
Initial score				
Cond.	77	80	77	78
Conf.	77	80	77	78
Days on test	196	196	196	196
Gain				
Total	407	478	474	460
Average	2.08	2.44	2.42	2.35
Efficiency of feed utilization #TDN/100# gain or #Gain/100# TDN				
Final weight	830	880	921	882
Final score				
Cond.	-	-	-	-
Conf.	-	-	-	-

Montana Agricultural Experiment Station

Feed Lot Performance (Bozeman--Heifers and Crossbreds R.O.P. 140 days)

Breed	Hereford	Hereford	Angus
Line	R.O.P.	Show Type	R.O.P.
Sex	H	H	H
Number on test	3	11	11
Average Age on test	226	260	237
Initial weight	405	463	472
Initial score			
Cond.			
Conf.*	74.74	79.6	76.3
Days on test	140	140	140
Gain			
Total	254.3	205.3	235.0
Average	1.82	1.47	1.63
Efficiency of feed utilization			
#TDN/100# gain or	-	-	-
#Gain/100# TDN			
Final weight	659.5	674.2	701.0
Final score			
Cond.			
Conf.*	74.6	80.3	77.4

Montana Agricultural Experiment Station

Feed Lot Performance (Bozeman--Heifers and Crossbreds R.O.P. 140 days)

Breed	Angus	Hereford-Angus	
Line	Show Type	Crossbred	
Sex	H	Heifers	Steers
Number on test	3	4	3
Average' Age on test	217	225	215
Initial weight	416	419	401
Initial score			
Cond.			
Conf.*	79.4	-	-
Days on test	140	140	140
Gain			
Total	202.6	260.0	348.0
Average	1.45	1.86	2.49
Efficiency of feed utilization #TDN/100 # gain or #Gain/100 # TDN	-	-	-
Final weight	615.3	679.0	748.0
Final score			
Cond.			
Conf.*	73.0	-	-

Montana Agricultural Experiment Station

Feed Lot Performance (Bozeman--Bull Indexing R.O.P. 140 days)

Breed	Hereford	Hereford
Line	A. R.O.P. Linebred	B. Show Type
Sex	B	B
Number on test	8	1
Average Age on test	222	256
Initial weight	454.4	506
Initial score		
Cond.	-	-
Conf.	82.1	80
Days on test	140	140
Gain		
Total	344.9	393
Average	2.46	2.84
Efficiency of feed utilization		
#TDN/100# gain or #Gain/100# TDN	487	440
Final weight	799.3	904
Final score		
Cond.	-	-
Conf.*	74.9	80.0

* A. H. Form No. 522, U.S.D.A.

Montana Agricultural Experiment Station

Feed Lot Performance (Bozeman--Bull Indexing R.O.P. 140 days)

Breed	Angus	Angus
Line	C. R.O.P.	D. Show Type
Sex	B	B
Number on test	2	2
Average Age on test	243.5	200
Initial weight	590.5	478
Initial score		
Cond.		
Conf.	85.5	85.5
Days on test	140	140
Gain		
Total	322.5	307
Average	2.30	2.19
Efficiency of feed utilization		
#TDN/100# gain or #Gain/100# TDN	575	554
Final weight	913	785
Final score		
Cond.		
Conf.	81.5	77.0

UNIVERSITY OF NEVADA

I. Station: Nevada Agricultural Experiment Station, Reno, Nevada

II. Project Title: The effect of environment on selection for traits of economic importance, the relative value of several selection criteria, and reproductive studies in range beef cattle

III. Personnel:

Experiment Station:

J. F. Kidwell, H. J. Weeth, V. R. Bohman, D. W. Cassard,
J. E. Hunter, C. R. Torell, J. D. Mankin, W. B. Dye,
J. A. McCormick, permanent and temporary farm labor, and
student assistants

U. S. Department of Agriculture:

R. T. Clark, Coordinator
C. E. Shelby

IV. Nature and Extent of Work Done This Year:

Experimental animals were managed and routine data collected in accordance with the project outline. Restricted funds and facilities render it impossible to pursue any interesting side lines suggested by the developing project. The graduate assistant formerly associated with the project completed his degree and was not replaced. A request that funds assigned for his salary be used for a part-time technician was not approved. Consequently, very little other than required routine work was accomplished during the year.

Analysis of the relations among conformation scores, body measurements and production factors in yearling steers was completed and a series of seven manuscripts prepared (see last year's report). The manuscripts were submitted to the Journal of Animal Science. The review committee felt there was too much detail for Journal publication and suggested detailed publication as an Experiment Station Technical Bulletin and publication of a condensation in two or three papers in the Journal of Animal Science. This suggestion is being carried out.

The essential conclusions include:

1. There is a high correlation among all components of conformation score and between all components and total score. In general, an animal is "all good," "all bad," "all intermediate," etc.

2. None of the means of the body measurements or ratios studied were separated into distinct groups by either feeder or slaughter grades.
3. Forty-seven to fifty-seven percent of the variation in conformation score was accounted for by various combinations of body measurements and ratios among them as determined by multiple regression analysis.
4. Measures or combinations of measures might be found that are associated with conformation score. Suitable measures of body length appear to be the limiting factor.
5. There is no relation between feeder grade and subsequent rate or economy of gain.
6. Feeder grade is positively associated with carcass grade, dressing percent, and percent fat in the 9- 10- 11 rib. It is negatively associated with percent bone and muscle in the 9- 10- 11 rib. The relation between feeder grade and percent muscle in the 9- 10- 11 rib is contrary to popular belief.
7. Feeder grade is only slightly or not at all related to the percent of the various wholesale cuts.
8. There is a high relation between feeder score and feeder price, a lesser association between feeder grade and slaughter price, and a small relation between feeder grade and carcass price.
9. There is no relation between slaughter score and rate or economy of gain.
10. There is a fairly high relation between slaughter score and carcass score, dressing percent, and percent bone, muscle, and fat in the 9- 10- 11 rib. The negative relation between slaughter grade and percent muscle is contrary to popular belief.
11. There is a low but significant relation between slaughter score and percent of the wholesale cuts. Higher-grading steers yield a lower proportion of round and a higher proportion of plate.
12. There is a high relation between slaughter grade and slaughter price and a lesser relation between slaughter score and carcass price. These results tend to support and extend those of previous investigations.
13. Body measurements of feeder steers bear little relation to subsequent rate and economy of gain, economic factors, or carcass traits.

14. Body measurements at slaughter are not related to rate or economy of gain.
15. Height at withers, height at hooks, chest width, and the ratio height at withers/heart girth are associated with certain economic traits.
16. Desired proportions appear to be low at withers and hooks and wide of chest relative to heart girth.
17. Relations between slaughter and carcass measures are low.
18. Multiple regression of various production factors on feeder measurements indicate little relation.
19. Feeder measures bear little relation to carcass grade.
20. The means of slaughter measures of height at withers, height at hooks, and the ratio height at withers/heart girth were separated by carcass grades.
21. Although few of the measures studies were sufficiently associated with the production factors to be of any practical value, it is possible that definitive measures may be found.
22. Correlations among body measurements are generally quite high.
23. The high correlation between heart girth and weight, and the much lower coefficient of variation of heart girth, suggests it is a more suitable measure of size than is weight for studies of growth and form.
24. Changes in measures and ratios during fattening were observed. The greatest increase was in heart girth, followed by height, round, length, and width measurements. Rate of change was greatest for heart girth.
25. Percent shrink is not associated with any of the other carcass traits.
26. Carcass score is largely determined by the percent of fat in the carcass.
27. Higher-grading carcasses yield more fat, less bone and muscle, and higher percent of loin, rib, and plate, and a lower percent of round and chuck. These relations deserve more careful study.

28. Relations among the percent of the five wholesale cuts studied also require further study.
29. Carcass score and dressing percent are positively associated with carcass value.
30. Percent round is negatively associated with carcass value, as is percent chuck, bone, and muscle. Percent loin, rib, plate, and fat are positively associated with carcass value.
31. Rate and economy of gain are not associated with carcass value.
32. Feeder price is not an accurate indicator of carcass value.
33. Differences in carcass and economic traits due to carcass grade are small but real.
34. The eighth rib was obtained from the right side of each of 49 yearling steers for consumer preference studies. Each steak was broiled to an internal temperature of 60° C. A panel of 4 men and 3 women scored a sample of each steak for tenderness, flavor of muscle, flavor of fat, quantity of juice, and quality of juice. A judge x carcass grade interaction was observed for quantity of juice. One judge consistently scored lower than the others for the remaining traits. There were no differences among the remaining judges or no differences due to grade. A correlation analysis indicated no association between tenderness score and fatness, average daily gain, or any of the other preference measures. Flavor of muscle was associated with percent fat, average daily gain, and quality of juice. The data indicate quality of juice is more dependent upon muscle constituents than on fatness. The data are too meager to warrant generalization, but clearly suggest the need for further study.

A pilot experiment with rats to study genetic-environmental interactions is being conducted (see last year's report). A population with maximum genetic variability was established by crossing four inbred lines. Four lines were established from the four-way cross. They are:

1. Standard laboratory ration selected for 70-day weight
2. Standard ration - random selection
3. High roughage ration, selected for 70-day weight
4. Roughage ration, random selection

Data from the first four selected generations have been analyzed and summarized. The means are presented as follows:

28- and 70-day Weight - Means

Generation	Day	Roughage Male	Random Female	Roughage Male	Select Female	Standard Male	Random Female	Standard Male	Select Female
		Males: $N=177$ $X=68.75$		Females: $N=171$ $X= 65.63$					
unselected) 4-way cross)	28								
	70	235.4	170.9	233.1	165.5	255.6	177.1	247.3	169.6
1st	28	58.75	56.91	62.97	56.86	56.64	54.69	64.27	59.57
	70	177.8	150.17	196.73	149.23	222.39	159.14	219.60	167.80
2nd	28	49.59	45.30	58.33	49.75	54.48	51.66	58.53	57.81
	70	175.72	137.07	189.60	153.62	217.76	161.38	225.87	177.00
3rd	28	49.86	45.60	54.79	52.29	56.78	54.31	58.70	55.25
	70	157.46	136.67	175.21	147.97	204.41	162.08	243.00	130.12
4th	28	50.58	53.50	64.16	59.00	56.38	53.41	67.46	65.55
	70	178.55	144.82	204.68	166.36	235.38	174.34	272.7	192.5

Selection response has been erratic. In some instances, there was an actual decline for three generations. In all cases, selection differentials were positive. Heritability estimates varied widely depending on the method of computation. The limited numbers result in large sampling error.

V. Summary of Progress and Conclusions to Date:

A fairly comprehensive summary was included in last year's report. Progress during the past year has been restricted to routine developments.

Application of Findings: Most of the significant findings resulting from this project have been published. The literature citations are given in the yearly reports. Virtually none of these has been applied by the industry. This is not entirely a fault, as some conservatism is wise. There is, however, a fairly complete breakdown in communication between technical personnel interested in this project (in Nevada) and the Nevada beef cattle industry. This situation has some advantages as well as disadvantages. The chief advantage is freedom of technical personnel from interruptions and industry pressures.

VI. Work Planned for the Future:

The major future effort is dictated by the project outline. The primary ultimate goal is to study the influence of environment on effectiveness of selection. The practical objective is to evaluate the

current practice of growing and selecting range bulls in a more optimum farm environment. A second objective is to study selection criteria for traits of economic importance in beef cattle and to determine genetic relations among them. Studies of genetic and environmental sources of variation in growth and form and in efficiency of feed utilization are of great interest. There is a desire to emphasize more fundamental work, utilizing laboratory organisms in the future.

VII. Publications and Manuscripts:

Kidwell, J. F., and V. R. Bohman. 1957. The ineffectiveness of meprobamate on growth and feed economy of White Leghorn cockerels. Growth 21(3):137-139.

Kidwell, J. F., J. E. Hunter, P. R. Ternan, C. E. Shelby, and R. T. Clark. 1957. Relations between conformation scores and production factors in yearling steers. (Abs.) J. Anim. Sci. 16(4):1017.

Kidwell, J. F., and H. J. Weeth. 1958. Sex ratios and litter size in the laboratory rat. J. Hered. (In press.)

Cattle Inventory Purebreds

PROJECT SUMMARY Nevada Agricultural Experiment Station

Breed	Hereford	Hereford	Hereford
Line	I R	II R	III R
Station	Reno	Reno	Reno
Bulls (12 mos. or over)	2	2	2
Cows (2 yrs. or over)	30	32	31
Heifers, yearlings	3	4	4
Bull calves	17	11	10
Heifer calves	5	12	7
Percentage used for breeding project	100	100	100
Estimated cash value			

Cattle Inventory
Purebreds

PROJECT SUMMARY
Nevada Agricultural Experiment Station

Breed	Hereford	Hereford
Line	I K	II K
Station	Knoll Creek	Knoll Creek
Bulls (12 mos. or over)	2	2
Cows (2 yrs. or over)	25	32
Heifers, yearlings	3	4
Bull calves	10	16
Heifer calves	6	3
Percentage used for breeding project	100	100
Estimated cash value		

Young Animals on Feed
Purebreds

	Hereford	
	Number individually fed	Number group fed
Bulls	64	None
Heifers	33	None
Steers	None	None

Land, Physical Facilities, and Equipment Used

Item	Number	Actual Cash Value	Percentage Used for Breeding Project
Reno station - Land, buildings, etc.	1	\$350,000	20
Knoll Creek station	1	100,000	60
Laboratories, etc.	1	100,000	30

Breed	Hereford				Hereford			
Line	I R				II R			
Cows bred	27				33			
Calves born								
Alive	24				28			
Dead	1				0			
Total	25				28			
Calves weaned	22				26			
% calf crop								
Birth	88.8				84.8			
Weaning	81.4				78.7			

	Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average								
Birth weight	-	-	-	-	-	-	-	-
Weaning age	240		240		240		240	
Weaning weight	17	500.3	5	505	11	511.8	12	455.4
Weaning score								
Cond.	-	-	-	-	-	-	-	-
Conf.	17	81.6	5	82	11	82.1	12	82.3

Cow Production Data

Nevada Agricultural Experiment Station

Breed	Hereford				Hereford			
Line	III R				I K			
Cows bred	29				19			
Calves born								
Alive	25				17			
Dead	2				0			
Total	27				17			
Calves weaned	20				17			
% calf crop								
Birth	86.2				89.4			
Weaning	68.9				89.4			
	Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average								
Birth weight	-	-	-	-	-	-	-	-
Weaning age	240		240		240		240	
Weaning weight	10	477.0	7	467.1	10	376.0	6	355.0
Weaning score								
Cond.	-	-	-	-	-	-	-	-
Conf.	10	82.5	7	84.4	-	-	-	-

Cow Production Data Nevada Agricultural Experiment Station

Breed	Hereford
Line	II K
Cows bred	26
Calves born	
Alive	26
Dead	0
Total	26
Calves weaned	24
% calf crop	
Birth	100
Weaning	92.3

	Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average								
Birth weight	-		-		-		-	
Weaning age	240		240		-		-	
Weaning weight	16	361.9	8	318.8	-		-	
Weaning score								
Cond.	-		-		-		-	
Conf.	-		-		-		-	

Feed Lot Performance Nevada Agricultural Experiment Station

Breed	Hereford	Hereford	Hereford
Line	I R	I R	II R
Sex	Male	Female	Male
Number on test	17	5	11
Average Age on test	240	240	240
Initial weight	500.3	486.0	511.3
Initial score			
Cond.	-	-	-
Conf.	81.6	82.0	81.9
Days on test	140	140	140
Gain			
Total	196.3	127.0	185.9
Average	1.41	.91	1.33
Efficiency of feed utilization			
Lbs. Hayx2 ÷ grain/ lbs. gain	17.25	23.27	18.44
Final weight	697.1	613.0	697.7
Final score			
Cond.	-	-	-
Conf.	81.5	81.8	82.1

Feed Lot Performance Nevada Agricultural Experiment Station

Breed	Hereford	Hereford	Hereford
Line	II R	III R	III R
Sex	Female	Male	Female
Number on test	12	10	7
Average Age on test	240	240	240
Initial weight	455.4	477.0	467.1
Initial score			
Cond.	-	-	-
Conf.	82.3	82.5	84.4
Days on test	140	140	140
Gain			
Total	157.1	195.5	137.9
Average	1.12	1.40	0.98
Efficiency of feed utilization			
lbs. Hay ^{x2} + grain/ lbs. gain	19.47	17.32	21.32
Final weight	612.5	672.5	605.
Final score			
Cond.	-	-	-
Conf.	82.5	82.4	83.7

Feed Lot Performance

Nevada Agricultural Experiment Station

Breed	Hereford	Hereford	Hereford	Hereford
Line	I K	I K	II K	II K
Sex	Male	Female	Male	Female
Number on test	10	6	16	8
Average Age on test	240	240	240	240
Initial weight	376.0	335.0	361.9	310.3
Initial score				
Cond.	-	-	-	-
Conf.	81.3	80.8	81.1	80.6
Days on test	140	140	140	140
Gain				
Total	188.8	168.3	190.3	158.4
Daily	1.37	1.20	1.36	1.13
Efficiency of feed utilization Lbs. hay/lbs. gain	7.86	7.72	7.56	7.58
Final weight	564.8	503.3	552.2	477.2
Final score				
Cond.	-	-	-	-
Conf.	81.0	80.9	81.2	80.8

NEW MEXICO COLLEGE OF AGRICULTURE AND MECHANIC ARTS

I. Station: New Mexico Agricultural Experiment Station, State College, New Mexico

II. Project Title: Breeding beef cattle for southwestern ranges

III. Personnel:

Experiment Station:

R. L. Blackwell, J. H. Knox, and D. W. Zinn

U. S. Department of Agriculture:

R. T. Clark, Coordinator

C. E. Shelby

IV. Nature and Extent of Work Done This Year:

Matings have been made as planned and production data have been collected. Steer calves have been fed for slaughter to obtain feed-lot and carcass data. Slaughtering will be done at the college meat laboratory. Heifer calves were fed stocker rations during the winter and have been returned to the range. Individual bull feeding has been continued with a considerable body of data compiled to date. Numbers of breeding cattle have been increased somewhat.

The analysis of data has been continued as rapidly as possible. Heritability estimates (numbers in parenthesis) have been obtained for the following traits: weaning weight (31, 8), weaning grade (27, 38), yearling weight (71, 10), yearling grade (34, 40), yearling gain (32, 32), weight at end of feed period (70), daily gain in feed lot, (long yearling age) (76), slaughter grade (88), carcass weight (93), dressing percentage (26), carcass grade (59). These values were obtained from paternal half-sib correlation analyses.

Genetic, environmental, and phenotypic correlations have been obtained for these traits. The phenotypic correlations are thought to be fairly reliable, while the genetic correlations, it is hoped, will be indicative of the sign of the correlation and possibly whether they are large or small. This material is being prepared for publication.

Multiplicative correction factors to adjust for the effect of age of dam on weaning weight have been derived from data taken from two herds (approximately 3,000 observations). The factors obtained differed slightly for each herd, and appeared to be due to earlier development in one herd compared to the other. By combining the factors for the two herds the following values were obtained: 3 yrs.--1.090, 4 yrs.--1.060, 5 yrs.--1.030, 6 yrs.--1.014, 7 and 8 yrs.--1.000 (no correction), 9 yrs.--1.020, and 10 yrs.--1.053. It is believed that these correction

factors will remove the major portion of the variation due to age of dam from weaning weight data of similar range herds in the southwest, and possibly may apply to herds in general. Multiplicative factors seem more logical than additive factors.

Some estimates of the effect of the age of dam on yearling gain and yearling weight have been obtained. For gains, the age effects were the reverse of those for weaning weight, indicating a compensation for different preweaning environments associated with the age of dam. For yearling weights, the age effects were similar to those for weaning weight but were not so marked. This finding raises the question regarding the use of postweaning gains as criteria in selection without considering the previous environment due to the age of dam. Such selection might result in retaining for breeding purposes animals which have old or young dams rather than those genetically superior for rapid gains. It also indicates that care needs to be exercised in making matings for purposes of comparing sires so that sire differences will not be confounded with age of dam.

The study of inbreeding effects on performance is nearing completion. However, final results are not available at this writing.

More information on the lethal in the outcross line has been obtained. In addition, matings have been made by the Arizona and California stations, using a bull from the New Mexico Experiment Station herd that sired abnormal calves in the New Mexico outcross line. The purpose of these matings is to determine if there is some genetic relationship between this lethal and the genetics of bovine dwarfism.

V. Summary of Progress and Conclusions to Date:

The analysis of much of the existing data is nearly completed on many phases of the work undertaken. These studies will add considerably to knowledge of the relative importance of hereditary and nonhereditary factors affecting economic characteristics of beef cattle and the relationships between these traits. Many of the findings in this research have had direct application to the industry; more widespread use of these findings should contribute to more accurate selection procedures for improving beef cattle.

VI. Work Planned for the Future:

Increased emphasis will be placed on the study of the importance of heredity in carcass traits and the relationship between these traits and live animal merit on the range and in the feed lot. This will be an increased effort over that presently being made. Station personnel has been increased for this work in meats research by the addition of D. W. Zinn to the project.

VII. Publications and Manuscripts:

Blackwell, R. L., J. H. Knox, and C. E. Shelby. 1957. Genetic components of variance and covariance in weaning, yearling, and feedlot performance of Hereford steers. (Abs.) J. Anim. Sci. 16(4):1018.

Blackwell, R. L. 1958. Records make beef. Annual Livestock Edition. Western Farm Life.

Blackwell, R. L., and J. H. Knox. 1958. Scurs in a herd of Aberdeen-Angus cattle. J. Hered. (Submitted.)

Knox, J. H. 1957. Applying the principles of performance testing to cattle and sheep. Extension Research and Marketing Clinic. Kansas State College, Manhattan, Kansas: May 1957.

Cattle Inventory

PROJECT SUMMARY

Purebreds

New Mexico College of Agriculture and Mechanic Arts

Breed	Hereford	Hereford	
Line	Old Line	Out Cross	Line
Station	Main	Main	
Bulls (12 mos. or over)	11	11	
Cows (2 yrs. or over)	26	21	
Heifers, yearlings	6	4	
Bull calves	5	4	
Heifer calves	7	5	
Percentage used for breeding project	65	65	
Estimated cash value	\$15,200	\$12,850	
Grades			
Breed	Hereford	Hereford	Hereford
Line	Big	Medium	Compact
Station	Main	Main	Main
Bulls (12 mos. or over)	0	0	0
Cows (2 yrs. or over)	36	38	29
Heifers, yearlings	4	23	4
Steer calves	12	24	9
Heifer calves	13	23	9
Percentage used for breeding project	50	50	50
Estimated cash value	\$9,700	\$26,500	\$8,200

Young Animals on Feed
Purebreds

New Mexico Agricultural Experiment Station
Grades

Hereford Number individually fed		Hereford Number group fed		Hereford Number group fed	
Bulls	20		0		0
Heifers	0		15		36
Steers	0		3		32

Land, Physical Facilities, and Equipment Used

Item	Number	Actual Cash Value	Percentage used for Breeding Project
Range land	63,000 acres	\$189,000	33
Farm land	52 acres	52,000	33
Feed lots		30,000	50
Barns	2	120,000	70
Meat laboratory	1	100,000	10
Pathology laboratory	1	40,000	15
Calculators	4	2,800	60
Office equipment		600	60

OREGON STATE COLLEGE

- I. Station: Oregon Agricultural Experiment Station, Corvallis, Oregon
- II. Project Title: Improvement of beef cattle through breeding methods, using basic physiological differences in rate and efficiency of gains

Phases of Work

1. The effect of such factors as birth weight of calf, suckling gains, age put on test, weight on test, and score on feed-lot performance (Union and Central Stations).
 2. The effect of the male hormone (testosterone on rate of gain, feed efficiency, and carcass characteristics
 3. The development of a selection index for improving beef cattle
 4. The growth pattern of calves differing in rate and efficiency of gains
 5. The relation of nitrogenous and carbohydrate constituents of blood and urine to rate and efficiency of gains
 6. Further studies on heritabilities of production characteristics in beef cattle
 7. The relation of body scores and measurements to rate of gain, feed efficiency, and carcass characteristics
 8. Application of selection for greater rate and economy of gains on a ration composed primarily of roughage (Squaw Butte and Central Stations)
 9. The development and use of inbred lines of beef cattle
 10. The relation of feed digestibility to rate and economy of gain
- III. Personnel:
 - Experiment Station:
 - Central Station, Corvallis:
Ralph Bogart, Hugo Krueger, John Kaufman, D. A. Price,
Hugh Nicholson, G. I. Alexander, R. W. Mason, Floyd
Pahnish, and Sam Sabin

Squaw Butte-Marney Station, Burns:

W. A. Sawyer and Farris Hubbert

Eastern Oregon Branch Livestock Station, Union:

James McArthur

Malheur Experimental Area, Ontario:

E. N. Hoffman

John Jacob Astor Branch Station, Astoria:

H. B. Howell

U. S. Department of Agriculture:

R. T. Clark, Coordinator

C. E. Shelby

IV. Nature and Extent of Work Done This Year:

The three lines of Herefords and one of Angus at the Central Station have been continued by using 2 sires in each line. The performance in the lines appears satisfactory. A very outstanding Angus bull has been produced (4.5 standard deviations above the herd in index). The David line appears very uniform in all the production traits. One case of cancer eye developed last year. It is the first in 11 years in this herd and one of the few recorded for the Willamette Valley. It seemed important to test the lines; therefore, one bull from each of the 3 Hereford lines at Corvallis and one bull from the line at Union are each being mated to 16 to 20 cows at Union each year for 4 years. Steer calves will be evaluated by feed lot and carcasses. Bulls from each combination will be individually fed. Heifers from each combination will be kept in the herd and appraised by their calf production records. The David and Prince bulls also are being tested at Astoria.

The effects of birth date and age of dam on suckling gains have been estimated, with correction factor for each developed.

Genetic and environmental factors influencing the weaning weights of southwestern range cattle were evaluated through the joint efforts of the Oregon Agricultural Experiment Station and the Agricultural Experiment Station of Arizona. The study was conducted under the provisions of Beef Cattle Improvement Project W-1. Weaning weights of 329 bull calves and 332 heifer calves produced on desert grassland ranges of two ranches were accumulated in Arizona from 1949 through 1954. The calves involved were the purebred Hereford progeny of 11 sires. The data were analyzed and presented in thesis form, in partial fulfillment of the requirements for a Ph.D. degree at Oregon State College.

The threefold purpose of this study was as follows:

1. evaluation of genetic and environmental variables that mask the phenotypic manifestations of genes influencing preweaning growth
2. determination of correction factors that beef cattle breeders might use to compensate for these variables and thus distinguish genotypes that are conclusive to preweaning.
3. Estimation of the heritability of weaning weight after the complicating variables have been discounted.

The major variables evaluated were: (1) weaning age of calf, (2) age of dam, and (3) sex of calf.

Rate of gain within sexes was essentially linear between the ages of 121 and 323 days. The average daily gain of bull calves within this age range, with the 95 percent confidence interval, was 1.442 ± 0.146 pounds. The analogous value for heifer calves was 1.090 ± 0.120 pounds. These rates of gain differed significantly at the 1 percent level of probability, thus indicating that separate correction factors should be used to adjust the weaning weights of bull and heifer calves to a standard age of 270 days. The average daily gains within sexes were proposed as the correction factors.

Age of dam exerted a curvilinear influence upon age-adjusted weaning weights. The influence upon the weights of bull calves was significantly greater than the influence upon the weights of heifer calves (1 percent level). Correction factors proposed for the adjustment of weaning weights to a constant age-of-dam basis were:

<u>Age of Dam</u> (Yrs.)	<u>Correction (Lbs.)</u>	
	<u>Bulls</u> (Add)	<u>Heifers</u> (Add)
3	50	24
4 & 9	25	12
5 - 8	0	0

Bull calves were significantly heavier than heifers at weaning time (1 percent level), but the magnitude of the weight advantage varied among years on the same ranch and between ranches in the same year. The sex x year interaction on one ranch was highly significant, and the sex x ranch interaction was significant at the 5 percent level of probability. The sex x sire interaction within ranches and years was not significant at the usual probability levels. The significant interactions and the variable weight advantage in favor of bull

calves lead to the conclusion that a constant sex correction factor for general use would be of little value. The difference between the mean weaning weights of bull and heifer calves within ranches and years, after the weights have been adjusted for age of calf and age of dam, should be a reasonably realistic sex correction factor.

Estimates of the heritability of weaning weight were calculated within sexes. The estimate derived from the data on bull calves, within the approximate 95 percent confidence interval, was 0.28 ± 0.32 . The estimate based upon the weaning weights of heifer calves was 0.57 ± 0.41 . Because of the wide overlap of confidence intervals, the difference between the two estimates was considered to be insignificant.

The following blood constituents have been examined at 500- and 800-pound body weight:

- Blood amino acid
- Blood urea
- Blood acid
- Blood creatinine
- Blood haemoglobin
- Blood haematocrit
- Serum protein
- Serum albumin
- Serum globulins
- Total white cell count
- Differential white cell count
- Red cell count
- Mean corpuscular haemoglobin
- Mean corpuscular volume

At 800-poundsbody weight, the following additional constituents were studied:

- Serum alkaline phosphatase
- Serum acid phosphatase
- Blood and serum inorganic phosphate

A marked sex difference was noted in rate of gain within both breeds and within the 3 Hereford lines, male calves gaining more rapidly than female calves. The gains made by the males also were more economical in terms of feed consumed per 100 pounds of gain than the females. Within breeds and also within the Hereford lines, the males were significantly younger at 800 pounds body weight than the corresponding females.

Significant sex differences were recorded for serum alkaline and acid phosphatase, males having higher levels than females. (A positive and significant relationship was found between both phosphatases and rate of gain.) Blood and serum inorganic phosphate levels did not show the consistent sex difference exhibited by the phosphatases.

Within female calves, there appeared a consistent positive correlation in all lines between alkaline phosphatase and rate of gain. A somewhat less consistent correlation was observed in females between acid phosphatase and rate of gain. These correlations were observed to be independent of breed and line differences. The reason for the lack of relationship between the phosphatases and rate of gain in the male calves would seem to be due to the variable onset of puberty with a concurrent production of prostatic phosphatases which influence the serum levels of these enzymes.

The serum phosphatases--in particular, alkaline phosphatase--would appear to have some promise as a predictive tool in assessing rate of gain in female beef cattle at this weight.

Few significant line differences were noted in the other constituents studied at 300 pounds body weight. The haematocrit of the blood of Hereford males was significantly lower than that of the Angus males ($P < 0.05$).

The blood urea level of Prince and David males was significantly lower than that of Lionheart males ($P < 0.01$).

In total white cell count, the Prince females were significantly lower than the David females ($P < 0.05$). Also, in the number of lymphocytes the David males exceeded the Lionheart males ($P < 0.05$) and the Prince females had significantly fewer than the David females ($P < 0.01$).

The blood creatinine levels of Lionheart and Prince males were both significantly greater than the David males ($P < 0.01$). Also, the Hereford males had significantly higher levels than the Angus males ($P < 0.05$). The Prince females had higher levels than the David females ($P < 0.01$).

Very few sex differences were observed. In haematocrit, David males had a significantly lower level than the David females ($P < 0.05$). In total white cell count, the Angus males had a significantly higher count than the Angus females ($P < 0.05$). Also, the David males had higher levels than the David females ($P < 0.01$).

At 500 pounds body weight, blood haemoglobin of beef under uniform environmental conditions ranged from 9.7 to 14.0 gm. per 100 ml.,

with an average of 12.1 gm. per 100 ml. The hematocrit reading (corpuscle volume) ranged from 31.5 to 48.3 with an average of 39.6 percent of blood volume. Red cell counts ranged from 6.0 to 9.3 with an average of 7.73 million per cu. mm. Mean corpuscular volume was 51.8 cu. microns with a range of 43.9 to 59.5. Haemoglobin per cell ranged from 26.5 to 37.2 micro-micrograms with an average of 32.7. At 800 pounds body weight haemoglobin for Angus males was 13.6 gm., while for Hereford males it was 12.9 gm., and the corresponding hematocrit values were 47.0 and 42.2 percent for males of the two breeds. Red cell counts were 8.5 million per cu. mm. for Angus males and 8.0 million for Hereford males. The average values for males of the three Hereford lines ranged from 12.8 to 13.0 gm. for haemoglobin, 41.9 to 43.7 percent for hematocrit, and 7.8 and 8.1 million for red blood cells. The average values for heifers of the three Hereford lines ranged from 13.0 to 13.1 gm. for haemoglobin, 38.6 to 45.6 percent for hematocrit, and 8.0 to 8.8 million for red cell counts. There were no differences in any of these blood constituents associated with line of breeding within the Hereford breed. The leucocyte count for cattle averaged 9,630 per cu. mm., with a range of 6,600 to 14,000. Male calves had lower levels of haemoglobin and red cell counts than female calves at both 500- and 800-pound weights. Hereford male calves exhibited a lower average of haemoglobin, hematocrit, red cell count, and neutrophil percentage, and a higher lymphocyte percentage in the cellular constituents of the blood than the Angus male calves at both weights. Hereford females at 500 pounds body weight exhibited higher average lymphocyte and lower average neutrophil percentages than Angus females. Among the three lines of Herefords, the only differences between lines was that at 500 pounds body weight Prince females showed higher suckling gains and higher average eosinophil and neutrophil percentages than David females. Although blood haemoglobin, red cell count, and hematocrit values were highly interrelated, only haemoglobin values were correlated with rates of gain and feed efficiencies.

Data from the Squaw Butte station have been analyzed by IBM through the Western Regional Office at Denver. There are three studies included. Factors affecting birth weight, weaning weight, and cow productivity, and the effects of approximately 25 variables have been considered. Means by sexes show that steers are heavier at weaning than heifers and that years, which contribute to heavier weaning weights, also cause larger differences between the sexes to appear. Two- and three-year-old cows wean lighter calves than older cows but at Squaw Butte the relation of age of dam to weaning weight of her calf beyond three years is not clear-cut even though the data cover cows from two to three years of age, were gathered over a period of ten years, and include 741 calves.

A small herd (8 pregnant cows and 1 bull) of Beefmaster cattle were secured for testing their productive value under western Oregon conditions (cooperation of projects 1 and 153).

The effect that nutrition has upon the hormone content of the anterior pituitary is important from the standpoint of how this effect would alter the expected genetic improvement in a selection program designed to improve economy and efficiency of gain in animals.

Results of the assay indicate that the levels of injection 0.003620, 0.007641, 0.015280 milligrams of the pituitary material caused a significant increase in the weights of the thyroids of the chicks. However, the pituitary material from the six different rations did not produce a significant difference in thyroid weights of chicks.

The fact that rations fed the steers had no influence on gonadotrophic or thyrotrophic hormone contents of the pituitaries, even though some rations were very low in protein content, indicates that a low protein diet does not necessarily alter the hormonal activity of the pituitary gland, when fed only short periods of time. (There is the possibility that storage of gonadotrophic hormone was not altered, but that rate of secretion into the blood stream was varied by the low protein diet.) Further, the inclusion of hormones in the diet may alter the gonadotrophic content of the pituitary.

A study is being made on "crooked" calves. It appears that there is a genetic-nutrition interaction involved. Certain lines of breeding show this affliction whereas others do not, even in the areas where it is prevalent. It occurs only in certain areas. Similar blood lines to those which show this affliction in one area where it is prevalent show no incidence in the areas where it is not found.

Continuing studies on bloat indicate that inheritance is important. Three-generation pedigrees are now available on some animals which show clearly the inheritance, but the dominance or recessiveness is not yet clear. The source of the alfalfa seems to be important, the incidence and severity of bloat being much greater when the feed came from eastern Oregon in 1956 and 1957 than when it came from Portland in previous years and in 1958. The Lionheart line is still free of chronic bloaters and the Prince Line is still troubled the most by bloat.

Studies have shown genetic-nutritional-endocrine interrelationships in mice and rats. Some strains have hyper secretions of certain hormones, particularly thyroxine, and others require large amounts of certain members of the vitamin B complex. It has been shown that crosses may be very inferior because of the interactions of these inherited traits.

Since phosphorus deficiency is important in beef cattle, some studies have been made in which rats have been restricted to the same food intake as that eaten by phosphorus-deficient rats. Reproduction and body weight gains were markedly influenced both by lower food intake and by phosphorus deficiency. The effects of the deficiency were greater than those of restricted food intake, however.

Some beef animals may become ill and are treated with antibiotics. Later, some of these may be very low in fertility. It seemed advisable to determine if antibiotics caused the reduced fertility or if it resulted from inheritance or from the effects of the disease itself. Male rabbits were given therapeutic doses of terramycin, streptomycin, and penicillin after an initial period during which fertility level was determined from semen samples. A fourth group served as controls. There were no lasting effects from the antibiotics on fertility.

Mice were used for testing the interactions of genetics with nutritional level and sex with nutritional level on growth rate. The study shows clearly that certain lines of breeding do quite well on a ration high in roughage, whereas other strains must have a highly concentrated diet. Where the conditions are such that mice generally grow rapidly, the males grow much more rapidly than the females. However, where conditions are generally not desirable for rapid gains, there is little difference between the sexes in rate of gain.

Mice were used to study selection for larger and smaller weight at approximately the time of sexual maturity. Comparison was made in selection for both size groups of the effectiveness of selecting males by their individual merit with the effectiveness of selecting males whose mothers were most outstanding in weight for age. Females were selected by their individual merit in all lines. One mouse in each litter was randomly selected to represent the calf which would be produced by a cow. The differences between the monoparous mice and cattle would be generations which could be produced in a given time. Such factors as sex-linkage and gene interactions have been shown to be important. Selection for small size led to physiological disturbances and soon it was impossible to continue the selection without ending the lines. Selection for increased body size was not harmful, but also not very effective under the conditions of the experiment where no mathematical adjustments were made for various environmental factors which affect weight at maturity.

At the end of the experiment, and after a time comparable to eight years of beef cattle breeding, the lines selected for larger size were not different from the controls; but, the lines selected for smaller size were smaller than the controls. However, the controls increased in body size during this time. Heritability estimates varied from year to year indicating that genetic environmental interactions were

important. Heritability estimates were approximately twice as large when estimated from regression of offspring on dam as when estimated from regression of offspring on sire, indicating that maternal influences were about equally important with genetic influences.

Over-all heritability was 28 percent, heritability of sire's 45-day body weight was 22 percent, and of mother's 45-day body weight was 36 percent. The sons inherited about the same percent of the mother's 45-day weight (34 percent) as did daughters (33 percent). However, the sons inherited only 16 percent of the father's 45-day body weight, whereas daughters inherited about 26 percent of the father's 45-day body weight, indicating that sex-linkage is important.

Approximately 24 percent of the differences in body weight of male offspring were inherited and approximately 32 percent of the differences in body weights of female offspring were inherited. This is consistent with the fact that females are generally less variable in the characteristic studied than males and indicates that females (because of additional heterozygosity) are more adaptable than males.

Heritability of differences in 45-day body weight of females was somewhat larger in those lines where males were selected individually than in the lines where the males were selected on the basis of weight of mother. Heritability of differences in body weight of male offspring was much greater in the lines where the male parents were chosen by their mother's rather than their own individual merit--43 percent as compared with 20 percent for large body size, and 26 percent as compared with 4 percent for small body size.

Oxygen consumptions and asphyxiation times have been run on four groups of 20 mice each: males of a wild strain; females of the wild strain; male of the O strain (original Animal Husbandry strain); and females of the O strain.

Oxygen consumptions were run under control conditions, during treatment with thiouracil, and during recovery from thiouracil. Thiouracil was added to the diet at the level of 0.1 percent. Thiouracil had a gastrogenic effect but did not decrease oxygen consumption rates to any marked extent. The data are currently being processed.

Oxygen consumptions were very high, about four times the level of 1,200 ml./kg./hr. usually reported in the literature. Cross check with a crude colorimetric procedure has supported the high oxygen consumptions found.

VI. Work Planned for the Future:

It is planned that 3 lines of Herefords and 1 line of Angus at the Central station, and 1 line of Herefords at the Eastern Oregon Station will be continued with selection on the basis of performance as measured by suckling gain, rate and efficiency of gain, and score from 500 to 800 pounds body weight.

In addition, the Eastern Oregon Branch Livestock Station will breed cows to bulls from the 3 lines of Herefords at the Central Station and one line from Eastern Oregon Station to obtain calves from which an evaluation of the relative merit of the 4 lines can be made. The offspring produced from these matings will be used in other studies but will be allotted in such a manner that line and sire effects can be ascertained. The basis for evaluating the lines will be cow productivity of the female offspring and rate of growth of the steer offspring.

The John Jacob Astor Station will use bulls from 2 of the lines from the Central Station for evaluation of the lines.

All of the cattle produced at the Central Station will be photographed, scored, and measured at 500 pounds and at 800 pounds body weight. In addition, cows and calves will be weighed weekly until weaning and then the calves will be weighed each week up to 800 pounds body weight and their weekly feed consumption will be measured.

The Squaw Butte Station will continue the feeding of heifers individually on two levels of intake to determine if selections can be made under a lower feeding regime or if high rate of feedings is necessary. All heifers will be retained in the breeding herd and their calves will be individually fed to regress performance of offspring and dam. In addition, the heifers that have been individually fed the first winter of their lives and pastured the following summer will be returned to the feed lot and individually fed to determine repeatability of feed-lot performance as measured by rate and efficiency of gains. It is anticipated that a period of four years should give sufficient evidence to direct conclusions relative to the merit of the lines.

There will be a continuation in the analysis of data for the development of a mathematical description of growth in beef cattle. There will be considerable effort made to develop a means of describing generation position in our lines of beef cattle since we have in each line cattle ranging from foundation animals to those representing the third and fourth generation of selective breeding.

Studies will be continued on abnormal conditions such as bloat, cancer eye, opaque eyes, dwarfism, and hydrocephalus.

Physiological data will be obtained, including the following studies:

1. The electrophoresis of blood plasma will be used as a means of separating the proteins into various fractions. This will be studied in relation to productive performance.
2. Employing the paper chromatography technique, the urine and blood will be analyzed to determine the amino acid and ketosteroid metabolism. All of these studies will be related to rate and efficiency of gains.
3. The blood chemistry study will include determinations of uric acid, amino acid N, urea, creatinine, and creatine.
4. A hematology study will be made which will include white cell count, differential count, hematocrit, hemoglobin, corpuscular volume, and corpuscular hemoglobin.
5. Blood inorganic phosphate, serum inorganic phosphate, and acid and alkaline phosphatase activity will be related to rate and efficiency of gains.

Much emphasis will be given to analysis of data and the preparation of manuscripts for technical papers and bulletins.

VII. Publications and Manuscripts:

- Alexander, G. I. 1958. The serum phosphatases of beef cattle as indices for rate and economy of gains. M. S. Thesis. Oregon State College.
- Bhannasiri, Tim. 1958. The effect of antibiotics on semen production. M. S. Thesis. Oregon State College.
- Hudson, Frank A. 1958. Anaesthesia time as a measure of body fat in genetically different groups of lambs. Ph.D. thesis. Oregon State College.
- Krueger, Hugo, Hugh Nicholson, R. W. Mason, John Kaufmes, and Ralph Bogart. 1958. The effects of injected testosterone into lactating rats on the suckling gains of their offspring. J. Pharm. & Expt. Ther. 122(1): .
- Mason, R. W. 1958. Selection for body weight in synthetic monoparous populations of mice. Ph.D. thesis. Oregon State College.
- Mason, R. W., J. F. Bone, Ralph Bogart, and Hugo Krueger. 1958. Urogenital anomalies in calf born to beef cow treated with testosterone during pregnancy. J. Pharm. & Expt. Ther. 122(1): .

Nicholson, H. H. 1958. The effect of dietary factors upon the hormone content of the anterior pituitary. Ph.D. thesis. Oregon State College.

Pahnish, O. Floyd. 1958. Some genetic and environmental factors influencing the weaning weights of southwestern range cattle. Ph.D. thesis. Oregon State College.

Price, Donald A. 1958. The chemistry and hematology of blood from genetically different lines of growing beef cattle. Ph.D. thesis. Oregon State College.

Cattle Inventory
Purebreds Oregon Agricultural Experiment Station

Breed	Hereford	Hereford	Hereford	Angus
Line	Prince	David	Lionheart	Angus
Bulls (12 mos. or over)	5	12	5	4
Cows (2 yrs. or over)	20	17	16	21
Heifers, yearlings	8	3	3	10
Bull calves	11	4	10	6
Heifer calves	5	4	5	11
Percentage used for breeding project	100	100	100	100
Estimated cash value				

Young Animals on Feed
Purebreds

	Hereford Number individually fed	Angus Number individually fed
Bulls	5	2
Heifers	3	8
Steers	0	

Cow Production Data Oregon Agricultural Experiment Station

Breed	Hereford				Hereford			
Line	Prince				David			
Cows bred*	25				21			
Calves born**								
Alive	16				8			
Dead	5				0			
Total	20				8			
Calves weaned	-				-			
% calf crop								
Birth	64				38			
Weaning	-				-			
	Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average								
Birth weight***	6	76	10	70	11	66	3	64
Weaning age	190		204		209		201	
Weaning weight	6	342	10	390	11	369	3	351
Adj. weaning wt. - 180 days	350		354		237		321	
Weaning score								
Cond.	6	9.8	9	10.6	11	9.3	3	9.3
Conf.	6	11.4	9	10.7	11	10.1	3	9.8

* Cows bred (1957)

** Calves born (1958)

*** Birth weight (1957)

Cow Production Data Oregon Agricultural Experiment Station

Breed	Hereford		Angus	
Line	Lionheart		Angus	
Cows bred*	24		22	
Calves born**				
Alive	15		17	
Dead	0		1	
Total	15		18	
Calves weaned	-		-	
% calf crop				
Birth	62.5		77.3	
Weaning	-		-	

	Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average								
Birth weight***	7	75	3	63	5	62	12	58
Weaning age		210		221		170		196
Weaning weight	7	407	3	381	5	415	12	381
Adj. weaning								
wt. - 130 days		363		326		414		357
Weaning score								
Cond.	7	9.2	3	11.2	5	9.9	12	10.3
Conf.	7	10.3	3	10.3	5	11.1	12	10.3

* Cows bred (1957)

** Calves born (1958)

*** Birth weight (1957)

Feed Lot Performance Oregon Agricultural Experiment Station

Breed	Hereford	Hereford	Hereford	Hereford
Line	Prince	Prince	David	David
Sex	Bull	Heifer	Bull	Heifer
Number on test*	6	9	12	3
Average				
Age on test	245	210	268	282
Initial weight	500	500	500	500
Initial score				
Cond.	9.6	10.6	9.3	9.3
Conf.	11.4	10.7	10.1	9.8
Days on test	109	139	123	122
Gain				
Total	300	300	300	300
Average	2.80	2.19	2.55	2.47
Efficiency of				
feed utilization				
Lbs. feed/100 lbs.	639	785	766	778
of gain				
or				
Lbs. gain/100 lbs.				
of TDN				
Final weight	800	800	800	800
Final score				
Cond.	11.5	11.4	10.0	12.7
Conf.	11.5	12.1	10.4	11.6

* Number on test (1957-58)

Feed Lot Performance Oregon Agricultural Experiment Station

Breed	Hereford	Hereford	Angus	Angus
Line	Lionheart	Lionheart	Angus	Angus
Sex	Bull	Heifer	Bull	Heifer
Number on test*	7	3	5	12
Average				
Age on test	256	279		
Initial weight	500	500	500	500
Initial score				
Cond.	9.2	11.2	9.9	10.3
Conf.	10.3	10.3	11.1	10.3
Days on test	113	143	117	149
Gain				
Total	300	300	300	300
Average	2.36	2.10	2.60	2.03
Efficiency of feed utilization				
Lbs. feed/100 lbs. gain	625	830	729	981
or				
Lbs. gain/100 lbs. TDN				
Final weight	800	800	800	800
Final score				
Cond.	10.4	12.0	12.0	11.7
Conf.	11.0	11.0	12.0	11.6

* Number on test (1957-58)

U. S. RANGE LIVESTOCK EXPERIMENT STATION

I. Station: U. S. Range Livestock Experiment Station, Miles City, Montana

II. Project Titles:

APH dl-1 Rev. The development and testing of methods of measuring performance in beef cattle

APH dl-2 Rev. The development of superior lines of beef cattle

III. Personnel:

Experiment Station:

U. S. Range Livestock Experiment Station, Miles City
J. R. Quesenberry, R. R. Woodward, and F. J. Rice

U. S. Department of Agriculture:

R. T. Clark, Coordinator
C. E. Shelby

IV. and V. Nature and Extent of Work Done This Year and Summary of Progress and Conclusions to Date:

Project APH dl-1 Rev. The development and testing of methods of measuring performance in beef cattle

The principle objective of this project is to determine interrelationships that may exist between the more important growth factors, body form, and measures of carcass quality. Data were collected from 7 sire groups of steers marketed in South St. Paul again this year. A number of body measurements were collected on the carcasses in the plant, and rib samples from each sire group were sent to the Meats Section, Beltsville, for physical separation, and tenderness and palatability tests.

A number of correlations have been completed from these data for the period 1953-57, inclusive. Factors studied include birth weight, 180-day weight, gain, efficiency, final feed-lot, area of eye, thickness of fat, body length, leg length, round circumference, depth of 7th rib, thickness of 1st rib, thickness at top aitch bone, muscle fiber diameter (cooked and uncooked), tenderness score, shear test, percent lean, percent fat, percent eye, and percent TEP. A total of 210 steers were included, although the meats analyses were accomplished on only 56 head. The average 180-day weight of all steers was 431 pounds, final weight, 1,038 pounds, and dressing percentage, 62 percent.

As earlier studies at this station have indicated, relatively low correlations appear to exist between growth and carcass quality in this all-Hereford population. Thus far, few promising relationships have appeared which might aid in selection of the live animal for carcass improvement. One body form measure which appears worthy of more study is body length. Body length measurements were taken on the R.O.P. bulls this year within a relatively narrow weight range (850-950 pounds). Simultaneously, measurements were made from the anterior edge of the scapula to the posterior portion of the tuber ischii, using a caliper on either side of the bull. The maximum range in body lengths within 25 pounds weight groupings was 10.7 cms., which was approximately 6 percent.

Some breeders have suggested that a birth score might be of value in predicting subsequent performance or carcass merit. To test this theory, progeny test steers were scored at birth and the following relationships were determined:

Birth score and birth weight	.845**
180-day weight	.400**
Average daily gain	.125
Slaughter grade	.135
Carcass grade	-.070
Length of body	.456**
Area of eye	.149
Fat over eye	-.101

Project APH dl-2 Rev. Development of superior lines of beef cattle

Another Hereford line was culled during the past year after giving below-average results in 5 topcross tests at the station as well as in top crosses in cooperator herds. This line ranked the lowest of 9 lines in preweaning and postweaning gain tests (between-line comparisons). Several more supervised topcross tests were initiated this year with private cooperators. The tests include herds in California, Utah, and Montana. Two additional bulls from another line were sent to Arizona. Comparative topcross information is being collected from 2 bulls each from Miles City lines 1, 6, 9, and 10 in the Apache herd. The progeny of sires from other sources are similarly tested. Arrangements were also made with an Oklahoma breeder to provide information on mothering ability of heifers from the Miles City Line 12 along with heifers from the Colorado station.

Considerable time has been spent bringing inbreeding coefficients up to date. Mean F values for the 1957 calves and the year in which the line was established are listed below for some of the older lines:

<u>Line</u>	<u>F</u> <u>x</u>	<u>Year</u>	<u>Line</u>	<u>F</u> <u>x</u>	<u>Year</u>
1A	13.1	1934	5	13.7	1944
1B	18.6	1934	6	17.9	1947
1D	16.1	1934	9A	19.3	1948
1F	13.5	1934	9B	9.6	1948
4A	20.9	1944	10B	12.1	1948
4B	13.9	1944			

Only herds used specifically for within-line matings in 1956 are listed. Sublines of Line 1 were maintained mostly as closed herds until 1955, at which time they were converged so the F_x values are lower than they have been.

A linecross yearling bull was selected as the first herd sire for Line 14, started from selected matings including all lines. This bull calf recorded a test gain almost .2 lb. higher than any bull previously tested at this station. Sufficient matings were made to provide females for a two-sire line at the end of the second year.

In 1957, two Charollais bulls originating from different herds were bred to grade Hereford cows. Birth weights of the crossbred calves born this spring averaged 86.0 and 89.4 pounds (by sires). The 1958 mean birth weight of all Hereford calves was 76.9 pounds. One case of dystocia among 49 crossbred calves born resulted in the death of an 116-pound calf. An 128-pound crossbred calf was born without assistance. An 112-pound Hereford calf was heretofore the heaviest calf born alive in the station herd. Nineteen Charollais 2-, 3-, and 4-year-old cows were acquired in March 1958. Seventeen calves born to date averaged 77.2 pounds at birth.

Two Brown Swiss bulls were purchased in the spring of 1958. One bull is being bred to a random selected group of 30 Hereford cows during the 1958 breeding season.

The study of stillbirths in the station herd continues to disclose some interesting observations. The incidence of posterior presentations, in particular, is high in one line. There is a higher incidence of stillbirths (4.2 percent) in the inbred lines than in the test population (2.8 percent).

The 20 cows selected by head form measurements and mated with a known carrier bull produced 26 calves. Their average birth weight was nine pounds below the mean of the other Hereford calves; two were stillborn and one died shortly after birth. One calf is distinctly abnormal, showing some of the symptoms of a spastic at birth. To date no definite conclusions have been reached as to whether any of the stillborn or live calves are dwarfs.

VI. Work Planned for the Future:

The principal objective of the R.O.P. project will be to determine methods of live animal selection for quality improvement. Because of the necessity of making weight corrections for correlations involving length, area, and circumference measurements, it is hoped that arrangements can be made to market at a constant weight.

Various breeds and breed crosses will be tested, with Charollais and Brown Swiss to be used initially. It is planned that reciprocal crosses will be made between the various breeds tested. The samples of each breed will be obtained from several sources and, if possible, in relatively large numbers. For example, the Charollais females will be increased as funds are available. As information on the adaptability of various breeds and breed crosses is collected, inter se matings of the crosses may be made if the crosses exceed the parental breeds in the more important production and quality traits.

The Hereford lines will be continued as in past years with an effort being made to initiate additional topcross tests with other stations and private cooperators. In our opinion, it would be desirable to pool the information collected to date in the W-1 inbreeding studies to determine inbreeding regressions and topcross performances.

VII. Publications and Manuscripts:

Shelby, C. E., R. T. Clark, J. R. Quesenberry, and R. R. Woodward.
1957. Heritability of some economic traits in record of performance bulls. J. Anim. Sci. 16:1019.

Woodward, R. R. 1957. Producing feeder cattle. Mont. State Col.
Third Annual Beef Production School Proc. December 1957.

Woodward, R. R., and R. T. Clark. 1958. A Study of stillbirths in a herd of range cattle. J. Anim. Sci. (Submitted.)

Cattle Inventory U. S. Range Livestock Experiment Station
Purebreds PROJECT SUMMARY

Breed	H	H	H	H	H	H
Line	1	4	5	6	9	10
Bulls (12 mos. or over)	13	3	3	5	3	3
Cows (2 yrs. or over)	171	32	21	34	42	34
Heifers, yearlings	71	12	6	5	14	7
Bull calves	63	14	6	16	17	14
Heifer calves	63	12	11	15	20	16
Percentage used for breeding project	100					
Estimated cash value	154,900	15,100	10,250	16,550	18,975	15,250
Grades						
Breed	H					
Bulls (12 mos. or over)						
Cows (2 yrs. or over)	210					
Steer calves	33					
Heifer calves	30					
Percentage used for breeding project	65					
Estimated cash value	53,050					

Cattle Inventory
Purebreds

PROJECT SUMMARY
U. S. Range Livestock Experiment Station

Breed	H	H	H	Charollais	Brown Swiss
Line	11	12	14		
Bulls (12 Mos. or over)		3	3	3	2
Cows (2 yrs. or over)	29	35	23	19	
Heifers, yearlings	8	1	23		
Bull calves	9	10		10	
Heifer calves	15	15		7	
Percentage used for breeding project					
Estimated cash value	11,075	15,900	11,450	8,950	600
Grades					
Breed					
Bulls (12 mos. or over)					
Cows (2 yrs. or over)					
Steer calves					
Heifer calves					
Percentage used for breeding project					
Estimated cash value					

Young Animals on Feed U. S. Range Livestock Experiment Station
Purebreds

Hereford

	Number individually fed	Number group fed
Bulls	84	
Heifers		
Steers		
Grades		
Bulls		
Heifers		
Steers		56

UTAH STATE UNIVERSITY

I. Station: Utah Agricultural Experiment Station, Logan, Utah

II. Project Title: The development of breeding techniques and selection criteria for improvement of economically important characteristics in Hereford and Shorthorn cattle

III. Personnel:

Experiment Station:

J. A. Bennett, Doyle J. Matthews, A. J. Nyman, and Gren Owens

U. S. Department of Agriculture:

R. T. Clark, Coordinator

C. E. Shelby

IV. Nature and Extent of Work Done This Year:

Matings were made and performance records were collected according to the experimental plan for the development of lines of Hereford and Shorthorn cattle through mild inbreeding accompanied by selection based on performance.

An analysis was made of body measurements taken at birth on calves of the Hereford and Shorthorn herds. The measurements included height at withers, height at hips, depth of chest, length of foreleg, heart girth, length of head, and width of head. Simple correlations were significant and positive between all measurements. The height measurements showed the highest relationship. While the length and width of head were significantly related to the other measurements, the correlation values were all below 0.5. Shorthorn calves had larger body measurements but smaller head measurements than the Hereford calves. Male calves were equal to or larger than females for all measurements.

An analysis of birth weight and weaning weight on 402 calves of Hereford and Shorthorn breeding was completed. Age of dam, sex, and breed were found to influence birth weight. Calves from 2-year-old dams were 5.9 pounds and from 3-year-olds 4.0 pounds lighter than from cows 4 years old and older. Male calves were 1.6 pounds heavier than females and the Shorthorns were 2.4 pounds heavier than the Herefords.

Weaning weight was found to be significantly influenced by age of dam, sex, breed, time of birth, and age of calf at weaning. Calves from 2-year-old cows were 72.9 and from 3-year-olds 52.6 pounds lighter at weaning than from mature cows. Male calves were 31.7 pounds heavier than females. Shorthorn calves were 39.9 pounds heavier than Herefords and late born calves were 36.7 pounds lighter than those born earlier.

Studies were continued with tritium oxide and N-acetyl 4-Aminoantipyrine (NAAP) to determine their value for estimating body composition in live cattle. Estimates obtained with these chemicals were compared to fat determinations made on the rib cut from the carcass after the animal was slaughtered. The studies this year revealed a high relationship between fat estimations based on specific gravity of the 9, 10, and 11th rib and of estimates based on chemical determinations made on these cuts. Specific gravity readings can be made easily and rapidly, while chemical determinations require much time. It was found also that NAAP is transferred through the rumen wall to the rumen fluid. It was reported last year that tritium is transferred through the rumen wall and reaches equilibrium in approximately 380 minutes. The fact that these substances are transferred to the rumen fluid means that two or more blood samples will have to be drawn for determinations to provide a means of extrapolating back to zero time estimates.

Both tritium and NAAP give estimates of body fat that are in close agreement with estimates based on fat determinations in the 9, 10, and 11th rib cut. Tritium is more accurate than NAAP and fewer animals give unsatisfactory readings. A few animals, for unknown reasons, give very abnormal NAAP readings. An occasional animal gives abnormal tritium readings. These very likely result from failure to give proper dosage or from contamination with tritium, but other causes seem to be present in the case of NAAP.

Four more animals known to have produced dwarf calves were purchased and added to the herd used for biochemical studies of body fluids in regard to dwarfism. Attempts were made, without success, to concentrate sufficient amounts of the material that formed the "14" spot on chromatograms from urine to isolate this material in crystal form.

Performance testing for rate and efficiency of gain of selected animals from private breeders was carried on at a central station for the first time in Utah this past year. A grant from the Kennecott Copper Corporation made this possible. Thirty-nine young bulls from 13 different herds were tested. Charbray, Angus, and Herefords were represented. The breeders are very enthusiastic about this program.

V. Summary of Progress and Conclusions to Date:

Development of Hereford and Shorthorn lines of cattle is proceeding according to plan. Factors for adjusting weaning weights of calves at this station have been calculated.

Tritium oxide and NAAP give estimates of body composition in live animals that agree closely with specific gravity and chemical determinations made on the 9th, 10th, and 11th rib cut area. Tritium is a little more accurate than NAAP and there are fewer animals that give abnormal readings from its use.

Differences were observed in chromatograms prepared from dwarfs, carriers, and supposedly non-carrier male cattle. Subsequent microbiological assays showed that dwarfs excrete more glutamic acid than normal cattle. One area designated as the "14" spot has shown differences between known carrier and supposedly non-carrier males. More refined studies show that the "14" area is made up of at least 4 components. Indications are that one of these components may show qualitative differences between carrier and non-carrier animals, but a satisfactory system of separating the components has not yet been discovered.

VI. Work Planned for the Future:

1. Continue development of lines of Hereford and Shorthorn cattle.
2. Complete studies with tritium oxide and NAAP and determine their effectiveness for estimating body composition in live cattle.
3. Continue biochemical studies of body fluids in an effort to identify genotypes associated with the dwarf condition in cattle. Emphasis will be given to identification of the "14" spot which has given some promise of identifying carrier animals. Studies of body fluids of animals under stress such as insulin shock also will be made. These studies will be extended to include work with known carrier females this year.
4. Encourage and assist the extension livestock specialist in carrying out performance testing with young bulls from private breeders' herds and in expanding the performance testing in the state.

VII. Publications and Manuscripts:

- Bennett, James A. 1958. An analysis of birth, weaning, and feedlot performance data. Ph.D. Thesis. University of Minnesota.
- Henderson, George R., and James A. Bennett. 1958. Evaluating Hereford weaning weight. Utah State U. Ext. L. 29.
- Johnson, Merle W. 1958. Relationships among birth measurements of beef calves. M.S. Thesis. Utah State University.
- Utah Agricultural Experiment Station. 1953. A field day report. Utah Agr. Expt. Sta. and Ext. Ser.

Cattle Inventory
Purebreds

PROJECT SUMMARY
Utah Agricultural Experiment Station

Breed	Hereford	Hereford	Shorthorn
Station	Logan	Panguitch	Logan
Bulls (12 mos. or over)	7	3	5
Cows (2 yrs. or over)	25	49	25
Heifers, yearlings	6	11	10
Bull calves	11	20	6
Heifer calves	14	25	12
Percentage used for breeding project	90	100	90

Land, Physical Facilities, and Equipment Used

Item	Number	Actual Cash Value	Percentage Used for Breeding Project
Land - Panguitch	155 acres	\$31,000	90
Land - Logan	269 acres	80,000	90
Sheds, yards, equipment	4 units	50,000	100
Metabolism building	1	60,000	10
Maternity stalls, office room at beef unit	2	4,500	100

Cow Production Data Utah Agricultural Experiment Station

Breed	Hereford			Hereford		
Line	I			II		
Cows bred	35			55		
Calves born						
Alive	31			49		
Dead	2			3		
Total	33			52		
Calves weaned	27			44		
% calf crop						
Birth	94			95		
Weaning	77			80		

Cow Production Data Utah Agricultural Experiment Station

Breed		Shorthorn	
Line			
Cows bred	25		
Calves born			
Alive	23		
Dead	2		
Total	25		
Calves weaned	22		
% calf crop			
Birth	100		
Weaning	88		
</			

Feed Lot Performance

Utah Agricultural Experiment Station

Breed	Individually fed		
	Hereford	Hereford	Shorthorn
Line	I	II	
Sex	Bulls	Bulls	Bulls
Number on test	6	7	5
Initial weight	503	514	528
Initial score			
Cond.	1.7	2.3	1.6
Conf.	1.5	2.0	1.7
Days on test	130	117	146
Average daily gain	2.23	2.34	1.98
Efficiency of feed utilization			
Lbs. gain/100 lbs. TDN	23.25	23.31	20.20
Final weight	790	787	814
Final score			
Cond.	2.3	2.2	2.2
Conf.	2.2	2.1	2.3

Feed Lot Performance Utah Agricultural Experiment Station

Breed	Group Fed			
	Hereford*	Shorthorn*	Hereford**	Shorthorn**
Line	I		I	
Sex	Steers	Steers	Heifers	
Number on test	12	6	7	10
Initial weight	386	427	415	474
Initial score				
Cond.			2.0	1.8
Conf.			1.7	1.6
Days on test			124	
Average daily gain	1.64	1.56	1.12	1.34
Efficiency of feed utilization Lbs. gain/100 lbs. TDN				
Final weight	566	573	539	621
Final score				
Cond.				
Conf.				

* Limited grain feeding

** Stocker ration

STATE COLLEGE OF WASHINGTON

- I. Station: Washington Agricultural Experiment Station, Pullman, Washington
- II. Project Title: Improvement of beef cattle by selection and mild inbreeding within lines of the Hereford, Angus, and Short-horn breeds
- III. Personnel:
 - Experiment Station:
C. C. O'Mary, S. H. Fowler, and H. E. Ensminger
 - U. S. Department of Agriculture:
R. T. Clark, Coordinator
C. E. Shelby
- IV. Nature and Extent of Work Done This Year:
 1. Animal Changes Within Breeds
 - a. Angus: Nine cows and three two-year-old heifers were sold prior to July 1, 1957, which reduced the inventory in this herd. This was in keeping with an established policy to maintain approximately 25 breeding cows in each of the three breeds. The herd sire, Eileenmere 701, born May 2, 1944, is still active but has been bred in some cases to daughters out of his daughters. In view of his age and the close inbreeding, a decision was made to purchase a new herd sire of Eileenmere breeding. This was accomplished by obtaining Marycrest Eileenmere 11. One additional cow of Eileenmere breeding also was purchased. Weights were taken on the Angus cows at the time of weaning (October 11, 1957) and again before calving (February 15, 1958). The respective average weights for the cows at the two times were 1,017 pounds and 1,068 pounds.
 - b. Hereford: In an effort to obtain a dwarf-free herd of Herefords, eleven "pedigree clean" cows have been purchased. A new herd sire, L.M. Prince A Heir, has been acquired through a generous gift of \$4,000. This bull was purchased with a money-back guarantee should he prove to be a dwarf-carrier. For this breeding test, the known dwarf-carrier cows have been retained and others are being acquired. This necessitates a larger inventory of Herefords than is called for in the present policy.

- c. Shorthorn: An outbreak of Johne's disease had reduced the Shorthorn herd below the desired number. To improve the herd and increase the number, seven "typey" females were purchased. Also, a yearling bull calf valued at \$3,500 was given to the State College of Washington by the Broughton Land and Cattle Company. This bull is related to many of the cows in the herd and will help carry on a mild inbreeding program as set forth in the objectives of the breeding program.

2. Production Testing of Beef Cattle

Thirty calves from the 1957 calf crop were placed on a feeding trial. These were fed an all-pelleted ration. The composition of the ration is given below:

TABLE 1.--The composition of the all-pelleted ration fed to cattle on test

	Percent
Alfalfa hay	40.0
Molasses	5.0
Ground corn	26.5
Barley (steamed rolled)	15.0
Oats (steamed rolled)	5.375
Beet pulp, dried	3.25
Wheat bran	2.25
Soybean oil meal	1.75
Linseed meal	.35
Steamed bone meal	.175
Iodized salt	.15
Dried skim milk	.2
Yeast, irradiated	3 oz./ton

TABLE 2.--Analysis of the above ration

	Percent
Moisture	14.9
Total protein	12.3
Crude fiber	12.4
Ash	5.66
Ether extract	.30

Calves from three different sires were used in the feed-lot performance study. A sample of three animals (one steer and two heifers) from each of the sire groups was randomly selected for individual feeding. The remaining animals of a sire group were fed as a group, with the sexes separated. The number of animals and methods of feeding are shown in "Project Summary--Young Animals on Feed". The bulls were selected prior to going on the test as representing the two best-type male offspring from each sire. This also precluded the steers

from representing random selection. The heifers represented all of the available female offspring from each sire.

In an effort to cut labor costs and get a more uniform ration for the animals on test, a pelleted ration was obtained. The roughage was contained in the pellets. The pellets were self-fed and were available at all times to the group-fed animals and twice daily to the individually-fed animals. Because of one severe case of chronic bloat and another mild case, further modification of the pelleted ration will be made. However, the use of an all-pelleted ration appears to be valuable in performance testing. Some added labor was required for tying the individually-fed animals. This is shown graphically in Figure 1.

Shortly after weaning, all of the calves to be used in the study were weighed and placed on test. The calves were weighed at almost 28-day intervals thereafter, and rate of gain, feed consumption and feed efficiency figures were calculated for each time interval and for the entire period of 131 days. The extra time required for tying the individuals was recorded in man-minutes. The animals had chains around their necks at all times. A snap chain fastened to a ring at the individual feeders was used to restrain each animal at feeding time.

TABLE 3.--Feed^{1/}lot performance of beef cattle during an 131-day feeding test

Breed	Method of feeding	Sex	No.	Initial weight	Final weight	Average daily gain	Average feed (lbs.) per lb. gain
Angus	Group fed	Bulls	219	570	880	2.37	6.6
			230	611	892	2.14	
		Steers	222	510	750	1.83	
		Heifers	246	401	614	1.63	7.8
			265	306	510	1.56	
			229	387	584	1.50	
	Individually fed	Steers	238	482	694	1.62	7.5
		Heifers	244	474	702	1.74	7.5
			248	440	626	1.42	8.7
Hereford	Group fed	Bulls	213	606	910	2.32	6.6
			252	535	772	1.81	
		Steers	224	540	742	1.54	
		Heifers	235	516	778	2.00	8.4
			255	358	590	1.77	
			250	506	740	1.79	
			264	320	524	1.56	
			260	457	684	1.73	
			240	428	636	1.59	
	Individually fed	Steers	215	571	788	1.66	8.0
		Heifers	234	434	636	1.54	8.5
			256	437	674	1.81	7.0
Short-horn	Group fed	Bulls	247	442	722	2.14	7.1
			218	614	886	2.08	
		Steers	254	539	862	2.47	
		Heifers	237	489	734	1.87	8.0
			261	429	680	1.92	
			266	355	598	1.85	
	Individually fed	Steers	241	449	721	2.08	6.4
		Heifers	258	412	638	1.73	7.6
			217	486	695	1.60	8.7

^{1/} Add 43 days to weaning age (see "Project Summary--Cow Production Data") for average age of calves at the beginning of test.

Table 3 shows the initial weights, rates of gain, and feed efficiency. The initial weights varied from 306 lbs. to 614. Five of the six bulls and four of the six steers weighed over 500 lbs., while only two of the 18 heifers weighed over 500 lbs. at the start of the test.

The rates of gain varied from 1.80 lbs. per day to 2.36 for the bulls, from 1.54 lbs. to 2.47 lbs. per day for the steers, and from 1.42 lbs. to 2.0 lbs. per head daily for the heifers. The average daily gain for the three steers fed with a group was 1.98 lbs. per day while the average of those fed individually was 1.79 lbs. per day.

The effect of tying may have tended to make a difference since the heifers, which represent an unselected group, also showed a slight advantage for group feeding over individual feeding. The group fed heifers gained an average of 1.73 lbs. per day and those individually fed gained 1.63 lbs. per day.

The main purpose of individually feeding was to obtain comparisons of individual feed efficiency with group feed efficiency. Within the Angus breed the group efficiency was 7.8 lbs. of feed per lb. of gain whereas the average feed efficiency for individual feeding was 7.9 lbs. The group feed efficiency was 8.4 lbs. and the average individual feed efficiency was 7.8 lbs. for the Herefords. The Shorthorns had an average group feed efficiency of 8.0 lbs. and an average individual feed efficiency of 7.6 lbs. of feed per lb. of gain. The average feed efficiency for all group fed animals was 8.1 lbs. and for individually fed animals was 7.8 lbs. of feed per lb. of gain.

If this is a trend of less feed per lb. of gain for the animals individually fed as compared to group feeding, the gains do not appear to be correlated with efficiency between groups. However, this does agree with previous findings that gains for self-fed animals are a little higher than for hand-fed animals, but that gains are more expensive for the self-fed animals. The differences in efficiency then could be explained by differences in feeding methods.

The correlation between rate of gain and feed efficiency is considered to be high. In this test, the individually-fed animal with the best rate of gain did have the best feed efficiency. This steer had a daily gain of 2.03 lbs. and made an average of a pound of gain on 6.4 lbs. of feed. Also, the animal with the lowest gain had one of the poorest feed efficiency figures.

The extra time which was required for chaining the animals is indicated in Figure 1. Considerable time is involved at first in training the animals, but once they know where they are supposed to be, then little extra time is required. At the end of two weeks, it took about three minutes per feeding and this time remained constant thereafter. Further study is needed to determine whether the added information acquired justifies individual feeding.

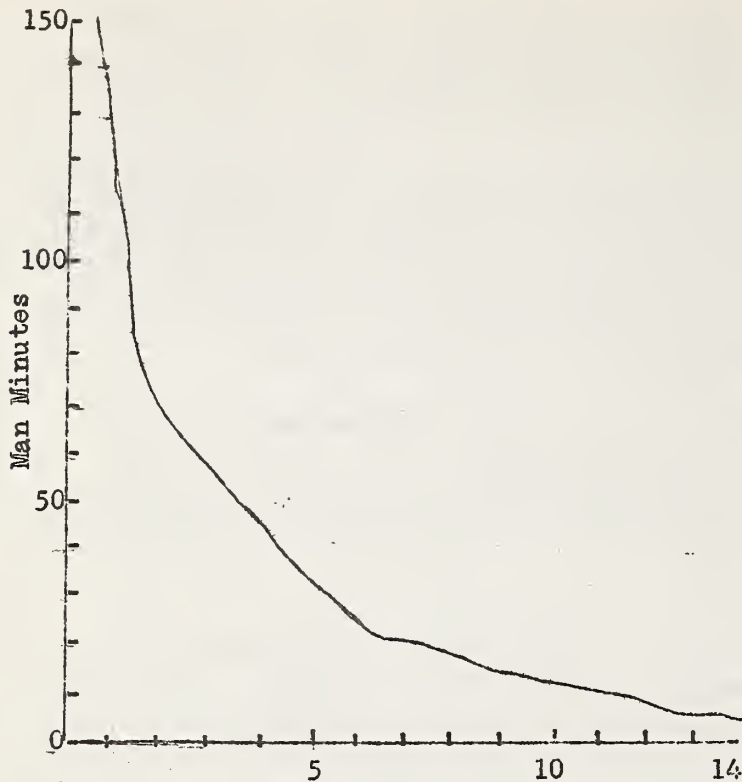


FIGURE 1.--Time required daily for individually tying nine beef calves for the first 14-day period.

3. Dwarf and Albino Study

Dwarf calves have been contributed by cattlemen from Washington and surrounding states. These calves are being assembled for research at the Washington Station. In assembling the dwarfs, one albino dwarf was obtained. A case history of this albino was studied, and the evidence indicated that two additional albinos had been produced in this family. The sire and dams of the albinos have been assembled, along with six other close relatives, and are being bred and cared for under our supervision. We have work already under way studying the effect of stressors applied to dwarfs, semen-staining affinity and general characteristics, microbiology of bloat, creatine-creatinine ratio in blood, alkaline-phosphatase, blood serum level, mineral components of hair, and differential hemolysis of blood.

A project outline has been prepared on albinism and dwarfism.

V. Summary of Progress and Conclusions to Date:

Thirty beef calves were placed on a performance test for 131 days. These were fed on a pelleted ration. All calves were divided according to sire groups and a sample of two heifers and one steer from the three sire groups were individually fed twice daily. The other animals were self-fed according to sire groups.

When individually fed animals were compared to group fed animals, the group fed animals had a slight advantage in gains but the individually fed animals had better feed efficiency. Some additional labor was required for the individually fed animals but once the animals became accustomed to being tied, the time required was less than one minute per animal per day.

Performance testing will be continued as a means of selecting the better animals (on type and rate of gain) for herd replacements.

Application of Findings

An all-pelleted ration seems to offer good possibilities in production testing, especially in saving labor. Performance testing can be used as a means of selecting herd replacements. Further work is needed to determine the effort which should be made in getting feed efficiency. Some further modifications of the ration are needed to alleviate the bloat problem.

VI. Work Planned for the Future:

Dwarfism and albinism are genetic factors which need further study to reduce (or prevent) economic loss to the cattlemen.

Results of a limited survey in the past six months follow:

- A. Field, physiochemical, and microbiological investigations have shown:
 - a. Dwarfs had lower respiration rates (significant) than controls; rectal temperatures and pulse rates were identical.
 - b. Among hematological values studied, dwarfs showed lower blood hemoglobin, hematocrit, and white count.
 - c. The electrophoretic analysis of plasma proteins did not show characteristic patterns.
 - d. There were no significant differences in serum alkaline phosphatase or creatine-creatinine ratio of the blood.
 - e. There was no common cause of death (post-mortem).
 - f. Dwarfs were either bloater, pot-bellied, or normal-bellied. Preliminary data indicate that there are possibly two bloat cycles in the bloater dwarf--one a diurnal cycle and the other recurring every two to three weeks. Normal-bellied dwarfs were less tolerant to bloat than bloater dwarfs.

- g. Protozoa in bloated dwarfs were either absent entirely or present in greatly reduced number and showing abnormally sluggish motility.
 - h. The fermentation rate (Warburg) in the rumen of bloated dwarfs was at endogenous levels within three hours after feeding. The metabolic activity of the microbial population was less in bloated dwarfs as measured by in vitro fermentation rates.
- B. Morphological and developmental investigations (live weight, measurement ratios of head, body, and long bones) support the hypothesis that the observed dwarfs could be classified into two major categories.
- a. True dwarfs (typical)
 - 1. Prenatal dwarfs; Dwarfs born showing different degrees of the typical head abnormalities, heavy breathing, pot belly and/or bloat (presumably as a result of different stages of development in the prenatal life at the time the defective gene came into operation).
 - 2. Postnatal dwarfs: Dwarfs born apparently morphologically normal, which later acquire the head abnormalities and heavy breathing, pot belly and/or bloat at different ages (presumably as a result of different stages of development in the postnatal life at the time the defective gene came into operation). These dwarfs may or may not breed and may die at different ages.
 - 3. Unsurviving dwarfs: Dwarfs born apparently morphologically normal, but die or abort before they are recognized as typical dwarfs. These animals we usually do not get.
 - b. Dwarf-like (atypical)
 - 1. Stunted nondwarfs as a result of nutritional, endocrinological, or pathological factors.
 - 2. Defective nondwarfs; Animals carrying unknown defective genes other than dwarfism, but showing the phenotypic expression of small size with a different degree of reaction. These animals have disproportionate conformation.
 - 3. Comprest types: Consequently, there is an overlapping between calves recognized as dwarfs and normal calves. This obscures the picture of identifying carrier animals by progeny testing. This also may be responsible for the variance in the results appearing in the literature and also in our results.

- c. Albinism and albino dwarfism have been observed in purebred Hereford calves. The albino dwarf showed similar morphological and anatomical anomalies in the head as colored dwarfs.

VI. Work Planned for the Future:

Feed-lot testing of the calf crop from the three breeds will continue. Herd replacements will be selected from these. Individual cards for cow performance will be kept up to date. These will be used as a means of culling the cow herd.

With the aid of Dr. E. S. E. Hafez, on leave from Cairo University, the following work on dwarfism and albinism will be in progress:

A. Physiochemical investigations on classified types of homozygous dwarfs

- a. Differential sensitivity to stressors
- b. Urine analysis for major metabolites
- c. Hair analysis, skin histology, and coat shedding
- d. Hormonal concentration of plasma
- e. Differential hemolysis of blood
- f. Sperm microstructure (electron microscope) and seminal plasma analysis (fructose, citric acid)

B. Microbiological

- a. The main purpose of this experiment will be to correlate protozoa motility and fermentation rate (as determined by Warburg manometry) of different groups of dwarfs and normals with the following: growth rate, score of bloat (cyclic), score of bloat (diurnal), blood biochemical values, and degree of dwarfism.
- b. The major amino acids will be determined qualitatively and quantitatively (paper chromatography). The results will be correlated to: Types of dwarfs, fermentation rates of the corresponding sample.
- c. Fatty acids production in the rumen (gas chromatography)

C. Genetic and embryological

- a. Anatomical studies will be carried out on the skeletal system of dwarf fetuses
- b. Test two albino-dwarf-carrier bulls by mating to albino-dwarf-carrier heifers, to dwarf-carrier heifers, and to dwarf heifers.

VII. Publications and Manuscripts:

Hafez, E. S. E. 1958. Dwarfism in beef cattle. Annual Beef Cattle Day. Washington State College.

Hafez, E. S. E., C. C. O'Mary, and M. E. Ensminger. 1958. Albino-dwarfism in Hereford cattle--a sublethal character. J. Hered. (In press).

O'Mary, C. C. 1958. Performance testing for profit (a preliminary report). Wash. State Col. Anim. Sci. C. 58-3.

Cattle Inventory
Purebreds

PROJECT SUMMARY
Washington Agricultural Experiment Station

Breed	Angus	Hereford	Shorthorn
Line	Eileenmere	F Baca Elation	N-Bar Gift
Station	Pullman	Pullman	Pullman
Bulls (12 mos. or over)	3	3	4
Cows (2 yrs. or over)	27	30	22
Heifers, yearlings	5	10	6
Bull calves	8	6	10
Heifer calves	11	9	7
Percentage used for breeding project	100	100	100
Estimated cash value	\$20,200	\$22,200	\$16,000
Grades	None	None	None

Young Animals on Feed* Washington Agricultural Experiment Station

	Angus		Hereford		Shorthorn	
	Individually fed	Group fed	Individually fed	Group fed	Individually fed	Group fed
Bulls	0	2	0	2	0	2
Heifers	2	3	2	6	2	4**
Steers	1	1	1	1	1	1

* Young animals on feed, 1957-58.

** One died from bloat.

Land, Physical Facilities, and Equipment Used

Item	Number	Actual Cash Value	Percentage Used for Breeding Project
Pasture	102 acres	\$35,700	50
Paving feed area at winter quarters		2,500	100
Partitions in feed-lot area	1	50	100
Scale (for weighing feed)	1	85	50
New animal breeding laboratory (well equipped)	1	50,000	100
Cattle laboratory annex (50% for dwarf study)	1	25,000	50

Cow Production Data^{1/} Washington Agricultural Experiment Station

Breed	Angus			Hereford		
Line	1			2		
Cows bred	27			23		
Calves born						
Alive	24			19		
Dead	1			3		
Total	25			22		
Calves weaned ⁶	24 ^{2, 3, 4}			18 ^{4, 5}		
% calf crop						
Birth	88.9			82.6		
Weaning	88.9			78.3		

	Bulls		Steers		Heifers		Bulls		Steers		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average												
Birth weight	2	66	2	72	5	51	2	76	2	72	8	62
Weaning age	2	218	2	214	5	191	2	206	2	223	8	188
Weaning weight	2	497	2	433	5	343	2	463	2	503	8	366
Adj. weaning wt. - 180 days	2	422	2	376	5	325	2	418	2	420	8	352
Initial feed-lot score ⁹	2	13.5	2	11.0	5	9.3	2	14.0	2	11.5	8	10.4
Final feed-lot score ⁹	2	13.5	2	12.0	5	11.0	2	13.0	2	13.0	8	12.5

1/ 1957 calves.

2/ Nine of these calves sold with their dams prior to July 1, 1957.

3/ Five calves were crossbred (out of Shorthorn bull).

4/ One steer selected for a show steer.

5/ Four calves out of known dwarf carriers.

6/ One calf died of bloat between weaning and the beginning of the feed test period.

7/ One calf slaughtered before weaning.

8/ Two calves were crossbred (out of Angus bull).

9/ Scores based on: 16 = fancy, 13 = choice, 10 = good, 7 = medium.

Cow Production Data^{1/} Washington Agricultural Experiment Station

Breed	Shorthorn					
Line	3					
Cows br.	17					
Calves born						
Alive	13 ⁷					
Dead	3					
Total	16					
Calves weaned ⁶	12 ⁸					
% calf crop						
Birth	76.5					
Weaning	70.6					
	Bulls		Steers		Heifers	
	No.	Av.	No.	Av.	No.	Av.
Average						
Birth weight	2	74	2	68	5	66
Weaning age	2	200	2	191	5	189
Weaning weight	2	448	2	431	5	366
Adj. weaning wt. - 180 days	2	394	2	415	5	352
Initial feed-lot ⁹ score	2	12.5	2	11.0	5	10.2
Final feed-lot ⁹ score	2	13.0	2	13.0	5	12.4

1/ 1957 calves.

2/ Nine of these calves sold with their dams prior to July 1, 1957.

3/ Five calves were crossbred (out of Shorthorn bull).

4/ One steer selected for a show steer.

5/ Four calves out of known dwarf carriers.

6/ One calf died of bloat between weaning and the beginning of the feed test period.

7/ One calf slaughtered before weaning.

8/ Two calves were crossbred (out of Angus bull).

9/ Scores based on: 16 = fancy, 13 = choice, 10 = good, 7 = medium.

UNIVERSITY OF WYOMING

- I. Station: Wyoming Agricultural Experiment Station, Laramie, Wyoming, and Gillette Experiment Station, Gillette, Wyoming
- II. Project Title: Criteria for improving effectiveness of selection in beef cattle
- III. Personnel:
 - Experiment Station:
 - P. O. Stratton, N. W. Hilston, C. O. Schoonover, C. P. Stroble, J. O. Tucker, M. C. Trueblood, permanent and temporary farm laborers, and graduate students
 - U. S. Department of Agriculture
 - R. T. Clark, Coordinator
 - C. E. Shelby

IV. and V. Nature and Extent of Work Done This Year, and Summary of Progress and Conclusions to Date:

Performance data as called for in the project were collected. Calves were weaned at approximately 180 days of age, at which time they were weighed, scored, photographed, measured and profiled. After a one-week adjustment, all weaned calves were put on feed test. Bulls were individually fed as facilities would permit (60 head) and the remainder group fed, as were the heifers, for an 168-day period. At the close of the feed test, the same measurement data that had been obtained at weaning were collected on all individuals. All calves at both stations were bled and blood typed.

Monthly weights were taken of all calves at the Laramie station during the suckling period. A great deal of fluctuation in individual gain by period was noted, yet in analysis the growth pattern approached linearity. The second month growth was superior for all breeds, probably accounted for by good early spring grass. Younger calves showed no advantage for growth rate by period; however, the majority of these calves were by first-calf heifers (two-year-olds). Persistency of milk production seemed more important for maximum suckling gain than did total production.

A custom-made pellet of coarsely chopped alfalfa, barley, corn, oats, bran, and molasses was fed again at the Gillette station. Considerable bloat trouble was experienced. When Baciferm, a penicillin, bacitracin mixture was added to the pellet, no relief from the problem was evident. There was a lower incidence in the group fed heifers than in the individually fed bulls. Fifteen head were slaughtered at the end of feed test and of these thirteen had a high

incidence of rumen parakeratosis. There was no relationship of severe parakeratosis to severe bloat. Those slaughtered bulls fed a meal mixture at the Laramie station had no presence of rumen parakeratosis. Also, Baciferm was very effective when fed to the few bloaters at the Laramie station.

The attempts by various stations and breeders to make comparison of performance data between test stations led us to a study to determine the results of bulls individually fed at various levels of nutrition. Four lots of nine bulls each were fed at four different levels of nutrition, varying only in ratio of roughage to concentrate. The following table is a summary of the 168-day feed trial:

Ration	TDN Level	Initial Weight	Gain	# Feed/ # Gain	# TDN / # Gain	Score Pretest	Score End-Test
I	66.4	399	354	7.42	4.93	4.67	5.22
II	63.3	413	366	7.33	4.64	4.60	5.00
III	60.1	414	346	7.33	4.39	4.30	4.56
IV	57.0	411	321	7.77	4.43	4.73	4.33

The gain difference by treatment was significant at the 5 percent level; the pounds TDN/pounds gain difference was significant at the 1 percent level. Although the scores were not significantly different, there is a decided trend to score the animals on the higher level of TDN higher.

Repeat head form measurements taken from 1954 through 1956 on Hereford heifers at the U. S. Range Station, Miles City, Montana, were studied in relationship to dwarfism and other economic factors. Significant differences in mid-forehead bulge was observed at all ages (6, 12, 18, and 24 months) between lines. The lack of dwarfs produced in the herd during the study gave little evidence as to the accuracy or usefulness of the measurements. A breeding study last breeding season using a carrier bull may help to substantiate some of these differences. The relationship between head form measurements and weight was studied. Correlations between weight at 6-month intervals up to 30 months, and head form measurements at 6 months showed decreasing relationships as the heifers advanced in age. The heifers studied were born within a 6-week calving period. To study the effect of age on weight and head measurements, the population was divided into three age groups depending upon date of birth. The younger age group had not compensated for age differences in weight nor in head form measurements by 24 or 30 months of age.

The immunogenetics laboratory processed blood samples from all of the 1957 calf crop from the Miles City, Gillette, and Laramie stations. An analysis is planned to determine the relationship of blood groups and systems to the estimated coefficient of inbreeding by Wright in all of the populations studied. The breeding plan at Gillette has been directed to a more detailed study of this sort by using four young bulls this season with approximately 12 females each, selected on blood type classification.

A total of 110 beef were slaughtered in the meats laboratory at Laramie during the 1957-58 fiscal year. Of these, 37 were 2-year-old steers; 20, 18-month-old heifers, and 53, performance tested bulls and heifers. Detailed carcass data were collected on all of these animals. The creatinine blood level on 90 head was studied to determine its relationship to the fat-lean ratio of the carcass as determined from colored rib-eye slides. A more detailed study of seven head of yearling bulls was made when the right half of the carcass of each was completely dissected to separate the bone, fat, and lean. The percentage of bone was found to be highly correlated with leg length, loin length, cannon bone green weight, and cannon bone length. The percentage of lean in the carcass was highly correlated with body length, loin length, and depth of round. Fat was found to be poorly correlated with all carcass measurements. Rib-eye area was much lower in relationship to lean, body length, and leg length than has previously been reported. The percent of lean in the carcass was inversely proportional to the percent of fat. The depth of round and body length measurements were the most promising in their relationship to total lean in the carcass, ($r = .87$ and $.89$, respectively). It may be possible that these two measurements could be useful and practical on the live animal. Further analysis of these data and previously accumulated information will be forthcoming.

Radiographs at birth, weaning, and yearling age, of the left metacarpal bone of all the Laramie 1957 calf crop have been obtained. Length and circumference measurements of the live animal cannon bone were taken at yearling age. These measurements are highly correlated with the radiograph measurements. Upon slaughter of those animals sacrificed for carcass data, the metacarpal bones were collected, weighed, thoroughly cleaned; then dried, weighed, and measurements taken. These data have been collected on all animals slaughtered; radiographs taken on only the Laramie performance tested yearling bulls and heifers. A complete analysis of these data and their relationship to carcass merit has been assigned to a Ph.D. candidate for his thesis problem. The relationship of radiograph measurements and dwarfism is being studied.

A new phase in the project was initiated this spring with respect to the feasibility of artificial insemination in beef cattle and a direct comparison of carcass merit of sire to offspring. Semen from four of the top-performing bulls on feed test at Laramie in each of the three breeds maintained was collected by electroejaculation. The semen was taken to the Colorado Bull Testing Laboratory, Fort Collins, evaluated and frozen, and returned to Laramie for storage. When sufficient ampules of each bull were obtained, the bulls were slaughtered and appraised for carcass merit. During slaughter, semen from 10 of the 12 bulls was successfully collected from the epididymis. Upon evaluation after freezing, we have available for insemination some of our better semen collected in this manner. We are using semen from those bulls selected on superior carcass merit on females at the Laramie Station to the extent which our breeding plans and facilities will permit.

Two cooperators in the Laramie area have initiated a systematic crossbreeding program. Plans have been arranged to collect performance data from the herds and to use the data and herds for demonstration.

VI. Work Planned for the Future:

A continuation of the project as planned. The Angus, Shorthorn, and Gillette Hereford herds have been closed to outside breeding since 1955, 1954, and 1952, respectively, and will be maintained as such. In cooperation with the Oregon station, a yearling Hereford bull will be used on part of the Laramie Hereford herd for a combining ability test.

A continuation of extended efforts toward carcass studies is our main objective. A sire-progeny carcass comparison should be possible in two years. The results of the usefulness of the metacarpal bone will be summarized, as will the feasibility of blood typing to estimate degree of homozygosity.

VII. Publications and Manuscripts:

Sabin, Samuel W. 1958. Birth to weaning growth in beef calves as an indicator of future performance. M.S. Thesis. University of Wyoming.

Schoonover, Carroll O. 1957. The relationship of head form to economic factors in Hereford heifers. Ph.D. Thesis. University of Wyoming.

Schoonover, Carroll O. 1957. A photographic grid used to measure rib eye areas. J. Anim. Sci. 16(4):957.

Wuthier, Paul R., and P. O. Stratton. 1957. The creatinine level of blood serum as an indicator of carcass composition. J. Anim. Sci. 16(4):961.

Cattle Inventory
Purebreds

PROJECT SUMMARY
Wyoming Agricultural Experiment Station

Breed	Angus	Shorthorn	Hereford
Line			
Station	Laramie	Laramie	Laramie
Bulls (12 mos. or over)	2	3	2
Cows (2 yrs. or over)	28	25	24
Heifers, yearling	5	6	10
Bull calves	15	9	8
Heifer calves	9	10	7
Percentage used for breeding project	100	100	100
Estimated cash value	\$9,695.00	\$9,745.00	\$10,170.00

Cattle Inventory
Purebreds

PROJECT SUMMARY

Breed	Hereford	Hereford
Line		Dryer (Grade)
Station	Gillette	Laramie
Bulls (12 mos. or over)	5	0
Cows (2 yrs. or over)	32	9
Heifers, yearlings	9	3
Bull calves	20	3
Heifer calves	11	6
Percentage used for breeding project	100	100
Estimated cash value	\$12,120.00	\$2,975.00

Young Animals on Feed
Purebreds

	Hereford		Shorthorn		Angus	
	Number individually fed	Number group fed	Number individually fed	Number group fed	Number individually fed	Number group fed
Bulls	10-G, 9-L	5-G, 3-L	14	0	18	2
Heifers		13-G, 13-L		10		5
Steers						
Grades						
Bulls	1	1				
Heifers		3				
Steers						

Wyoming Agricultural Experiment Station
Land, Physical Facilities, and Equipment Used

Item	Number	Actual Cash Value	Percentage Used for Breeding Project
Beef shed	1	\$5,237.30	100
Bull shed	1	2,491.29	100
Fencing		400.00	100
Open shed	1	309.88	70
Trench silo	1	422.00	100
Machinery leases		2,220.00	60
Electro ejaculator	1	520.48	90
Squeeze chute		450.00	100
Colorimeter		270.00	80
Beef equipment		300.00	100
Office equipment		525.30	60
Meats laboratory equipment		1,892.47	70
Semen storage unit		161.33	100
Spectrometer		4,000.00	40

Cow Production Data

Line Breed	Laramie Angus		Laramie Shorthorn		Laramie Hereford	
Cows bred	27		25		30	
Calves born						
Alive	26		25		27	
Dead	1		0		3	
Total	27		25		30	
Calves weaned	26		25		26	
% calf crop						
Birth	100		100		100	
Weaning	96		100		87	

	Bulls		Heifers		Bulls		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average												
Birth weight	21	53	5	50	15	71	10	64	13	76	14	66
Weaning age	181		181		186		180		166		171	
Weaning weight	21	388	5	354	15	404	10	350	13	351	13	335
Adj. weaning wt. -180 dys	387		351		395		350		374		351	
Weaning score												
Cond.	-	-	-	-	-	-	-	-	-	-	-	-
Conf.	21	6.	5	4.9	15	4.8	10	4.9	13	4.1	14	4.4

Cow Production Data Wyoming Agricultural Experiment Station

Line	Dryer		Gillette	
	Hereford		Hereford	
Cows bred	13		35	
Calves born				
Alive	12		32	
Dead	0		2	
Total	12		34	
Calves weaned	12		32	
% calf crop				
Birth	92		97	
Weaning	92		91	

	Bulls		Steers		Heifers		Bulls		Heifers	
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
Average										
Birth weight	2	80	6	73	4	70	17	73	15	66
Weaning age		167		169		144		193		189
Weaning weight	2	345	6	340	4	288	17	394	15	346
Adj. weaning wt. -180 days		358		360		343		370		330
Weaning score										
Cond.	-	-	-	-	-	-	-	-	-	-
Conf.	2	3.8	6	4.4	4	4.4	17	5.25	15	5.00

Feed Lot Performance

Wyoming Agricultural Experiment Station

Breed	Angus	Shorthorn	Hereford	Hereford	Hereford
Line	Laramie	Laramie	Laramie	Gillette	Dryer
Sex	M	M	M	M	M
Number on test	20	14	13	15	6
Average					
Age on test	196	201	181	205	173
Initial weight	398	420	365	381	352
Initial score					
Cond.	-	-	-	-	-
Conf.	6.0	4.8	4.1	5.25	4.15
Days on test	168	168	168	168	168
Gain					
Total	336.5	365.3	345.3	335.0	378.0
Average	2.00	2.17	2.06	1.99	2.25
Efficiency of feed utilization					
# TDN/100# gain	453.5	477.0	450.0	444.0	G. F. 433
or					
# gain/100# TDN	-	-	-	-	-
Final weight	735	785	711	716	729
Final score					
Cond.	-	-	-	-	-
Conf.	5.26	5.30	4.56	5.2	4.96

Feed Lot Performance Wyoming Agricultural Experiment Station

Breed	Angus	Shorthorn	Hereford	Hereford	Hereford
Line	Laramie	Laramie	Laramie	Gillette	Dryer
Sex	F	F	F	F	F
Number on test	5	10	13	15	3
Average Age on test	196	195	186	189	159
Initial weight	396	363	343	316	317
Initial score Cond. Conf.	4.9	4.9	4.4	5.0	4.4
Days on test	168	168	168	168	168
Gain Total	297	303	312	292	317
Average	1.76	1.81	1.86	1.73	1.88
Efficiency of feed utilization # TDN/100# gain or # gain/100# TDN	G.F.551	G.F.551	G.F.551	G.F.531	G.F.551
	-	-	-	-	-
Final weight	666	667	655	608	633
Final score Cond.	-	-	-	-	-
Conf.	5.8	5.54	4.98	4.84	5.1

BUSINESS MEETING

Tuesday, July 8, 1958 - 10:45 A.M.

The business meeting was called to order by Dr. Blackwell. Comments were requested from the Regional Administrative Adviser.

Dr. Wheeler reported that the total allotment of 9b3 funds to W-1 remains the same for 1958-59. Allotments to Colorado, New Mexico, and Oregon were reduced \$100 each, and the travel fund increased by \$300.

The general reaction of the committee of nine and the western directors to W-1 is good. The revisions made in the past year have served to allay the criticism that some of the state projects did not conform with the regional objectives.

The problem of informing the public of research accomplishments at the state and regional level was emphasized. Various methods of accomplishing this were explored. The necessity for keeping in close touch with extension personnel was cited. Considerable discussion on this topic followed.

Acceptance of new contributing projects at the Washington and Nevada stations was considered.

Dr. O'Mary gave a short talk on the proposed dwarfism and albinism project at Washington State College. The need for additional funds was stressed.

Dr. Wheeler said that no funds will be available in the 1958-59 fiscal year.

In general, it was felt that the project was too broad in nature, and that if all areas of the project were carried out in the detail and thoroughness with which they should be, the cost would be excessive. Also, the procedures were not specific enough in detail and the literature review incomplete.

Dr. Gregory felt that dwarfism and albinism should not be combined in the same project. Too, certain techniques would be required which could be done only at a limited number of institutions in this country.

Since the proposed project dealt largely with physiology, the question of whether such a project could be included in W-1 was explored in some detail. It was concluded that the objectives of W-1 were sufficiently broad to include the physiological approach to the solution of genetic problems.

It was moved and seconded that the project be rewritten in more detail with a comprehensive literature review and resubmitted for acceptance to the technical committee who would reply directly to Washington State College with a copy to the Denver office. Motion carried.

Dr. Wheeler explained that the technical committee does not have the responsibility for approval of a state contributing project, but instead, reviews it for conformity, accepts it, and submits it through channels for final approval by the committee of three, the SESD, and ultimately, the committee of nine. The Washington station can not divide their present allotment between the old and new projects and will have to finance the new project this year with no assurance that an allotment will be forthcoming next year.

Dr. Kidwell outlined briefly the work done on genetic-environmental interactions at the Nevada station, and its relationship to the proposed project. Some discussion of the project ensued.

It was moved and seconded that the Nevada project be accepted for conformity by the W-1 Technical Committee. Motion carried.

Invitations were extended to meet in 1959 at Colorado, Nevada, Utah, and Oregon. A motion was made and seconded to meet at the Utah station, Thursday and Friday prior to the Western Section meeting. Motion passed.

Comments were requested from Dr. Warwick.

Dr. Warwick said that ARS funds would be approximately the same for 1958-59. Several changes have been made in the current budget after consultation with Drs. Clark and Shelby.

Summaries of the results of the questionnaire rating the W-1 projects have been prepared for each individual station and will be distributed, giving the average rating, the range, any comments (unidentified) and the over-all rating. This information should be of value in the improvement of the individual projects.

Comments were requested from Dr. Burris.

Dr. Burris mentioned that SESD had prepared a list of all Hatch projects in beef cattle, sheep, and swine, and that ARS had prepared a similar list of all active line projects. The SESD manual of procedures has also been revised. Copies of all three are available upon request.

Project outlines should be revised currently to include any changes in procedure.

All projects should be registered with SESD on approval. If regional research or Hatch money is involved, they have to be approved by SESD.

Dr. Clark's greetings from Argentina were read:

"Please convey to the W-1 Committee when they meet at Tucson my best wishes for a profitable meeting. I am sure that Carl and Pahnish will demonstrate to the Committee what has been accomplished at that station since Carl left Denver and took over the direction of Animal Science at Tucson. He has put a tremendous amount of effort into the Arizona program and I feel confident that the W-1 Committee will fully appreciate that when they visit Tucson.

"The work at Arizona is of particular interest to me at this time while I am engaged in a mission which involves problems of ecology and adaptation to rigorous environments. There are many facets to a task of this nature and particularly when you are faced with planning programs in areas where no research in animal production has been done. That tests your ingenuity and particularly when you have to struggle along and try to learn a new language at the same time.

"The members of our Committee will be interested to know that extensive use is being made of artificial insemination in beef cattle in this country. By contrast the Argentine has no test program for assessing breeding stock, yet they are using artificial insemination successfully while we have a test program of a limited nature and are just beginning to use artificial insemination.

"So far they have not utilized growth stimulants, probably because the entire industry fattens cattle exclusively on grass and alfalfa.

"The grading scheme for carcasses is very involved and there is constant dissatisfaction on the part of producers and industry people.

"Disease control leaves much to be desired but in general the margins of profit in cattle are so small that most producers are reluctant to take on expenses that add to operational costs.

"I have observed dwarfism but only to a limited extent. Apparently, importations from the U.S. are primarily responsible, a sad commentary on "improved" breeding in our country.

"I regret that I have to miss the Arizona meeting but I will look forward to working with all of you later in the year. With kindest personal regards."

Dr. Stonaker, Chairman, and Prof. Willson were appointed to the Resolutions Committee. The following resolution was drafted:

"BE IT RESOLVED, That the W-1 Technical Committee express their appreciation to the University of Arizona for the fine hospitality accorded them and for the facilities which were made available. We should like particularly to thank the members of the Animal Science Department for their many services and courtesies.

"We especially want to extend to the wives of the staff our appreciation of their gracious hospitality and the excellence of the meals they prepared and served, and our gratitude for the many kindnesses shown our wives and families during their stay in Tucson.

"We feel that during our visit we have gained a considerable insight into the excellent research program under way and a greater appreciation of the livestock industry in Arizona."

Dr. Bogart was confirmed as incoming chairman.

Dr. Warwick brought up the subject of approaching the breed associations to allow registry of calves sired artificially in experimental studies at educational institutions by dead bulls or by bulls of less than one-quarter ownership. Dr. Warwick felt that he would be in a stronger position to approach the breed associations if concrete action were taken by the three technical committees.

The motion was made and seconded that a resolution be prepared on this subject. Drs. Stratton and O'Mary were appointed to prepare a resolution.

The following resolution was submitted:

"Purebred beef cattle registry associations do not register calves produced by artificial insemination unless the breeder has at least one-fourth ownership of the sire. They do not register calves produced by artificial insemination using semen of deceased sires. The usefulness of germ plasm for experimental research is often restricted by these rules. Therefore, be it resolved that the W-1 Technical Committee request the breed associations to relax these restrictions in the case of calves produced in research herds maintained as part of the cooperative research program of the Beef Cattle Research Branch of the U. S. Department of Agriculture and State Experiment Stations."

Meeting was adjourned.

DISCUSSION OF REGIONAL PUBLICATIONS AND MEETING
WITH EXTENSION SPECIALISTS AT DAVIS

Wednesday, July 9, 1958 - 3:30 P.M.

Dr. Bogart led a discussion on the subject of regional publications and of recommendations for a National Beef Cattle Improvement program which could be presented to extension specialists from the western region at the July 14th meeting at Davis.

Considerable discussion relative to the kind of publication needed ensued. Two major types of publications were discussed:

- (1) A technical or semi-technical publication for scientific workers and extension personnel, summarizing the research findings obtained in W-1 with some attempt to relate them to range cattle production.
- (2) A popular publication for extension personnel and ranchers, outlining the ideal procedure for a Regional or National Beef Cattle Improvement program, together with suggested modifications of the ideal to meet various other situations, plus an idea of what would be lost by not following the ideal.

Since no action had been taken on the resolution passed at the 1957 meeting to prepare a publication summarizing the research accomplishments of W-1, the following resolution was adopted:

RESOLVED, That, based on the resolution passed by the W-1 Technical Committee at the meeting in Moscow in 1957, the Coordinator's office proceed with developing an outline and obtaining the necessary information for the preparation of a manuscript which will be a summary of W-1 results to be published as a regional publication.

It was suggested that a film on beef cattle improvement suitable for use on television and other media be made. Such a film might have a much greater impact than a bulletin read carefully by only a few people.

Dr. Warwick mentioned that the other regions are preparing similar publications summarizing the work done in their regions.

No concrete action was taken on the popular publication.

The matter of recommendations for a National Beef Cattle Improvement program which could be presented to the extension specialists at Davis was considered.

Dr. Hodgson mentioned the following problems which need to be settled in the minds of most research people: "What relation do you want with extension and industry in this ROP program? How much leadership should the group give to it? Are the research recommendations to be turned entirely over to extension for them to carry it forward independently?"

The responsibility of the research worker to evaluate research findings which are often conflicting and unintelligible to the extension people, and to make recommendations based on the studies, was pointed out by others. The extension worker must know what data should be collected, how best to collect it, and how to use it in the breeding program.

Results of the national questionnaire prepared by Dr. Warwick and Mr. Bell were discussed. A motion was made that the W-1 Technical Committee accept and recommend the majority vote on each of the items in the questionnaire. Much opposition arose. The motion died for lack of a second.

Considerable discussion of the problems entailed in the development of a National Beef Cattle Improvement program ensued. The variety of environmental and managerial regimes under which tests would be conducted make it mandatory that considerable flexibility in procedure be included in the program.

It should be recognized that the tendency to make inter-herd comparisons will increase as the national program develops. Since this program is designed for improvement within the individual herd, only intra-herd comparisons should be made.

The group finally agreed to go on record as endorsing a National Beef Cattle Improvement program entailing minor variations in procedure between different sections of the country. The following motion was approved:

The W-1 Technical Committee endorses the broad perspectives of a National Beef Cattle Improvement program, and, furthermore, makes the recommendation that within each state in the western region, the beef cattle extension and research workers devise a plan they consider appropriate to their state and that they submit this plan to Mr. Charles E. Bell, Chief, Animal Industry Branch, Federal Extension Service, and Dr. E. J. Warwick, Chief, Beef Cattle Research Branch, Agricultural Research Service, for their consideration in the fabrication of a regional program, and we urge the other regions to carry out similar programs.



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U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
ANIMAL HUSBANDRY RESEARCH DIVISION

HANDBOOK
OF
THE 2ND W-1 WORKSHOP

FROM THE
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CATTLE RESEARCH

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held
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July 7 - 10, 1958
Tucson, Arizona

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HANDBOOK
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W-1 Workshop
Tucson, Arizona
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ANIMAL HUSBANDRY RESEARCH - ORGANIZATION AND PROSECUTION

R. E. Hodgson
Director, Animal Husbandry Research Division
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It has been estimated that in order to feed the 230 million Americans that are expected in this country by 1975 at least as well as we are fed today, it will require an increased food production of 35 to 40 percent. Such an increase, on top of the great increases in production that have taken place in the past decade, clearly defines the task ahead for the American farmer. We will need at least a third greater production of animal foods. This increase in our food supply will have to come from essentially the same agricultural land area, and I believe, essentially the same size livestock population. In other words, the increases must come more from vertical expansion rather than horizontal expansion, from increases in output per acre and per animal unit more than from increased acres and animals.

Our agricultural production and the progress it has made, to a very large extent, is the result of the application of technological production know-how developed in the public-supported experimental stations and laboratories. Future advances in agricultural production and efficiency will depend even more on the findings in these stations and laboratories and the effective application of these findings on farms and ranches. The agricultural research workers, therefore, are most significant individuals in the future welfare and advancement of our agricultural industry and our country. What they have to work with and how well they perform their tasks will, in no small degree, dictate future progress.

Agricultural research on an organized basis in this country is a little more than 100 years old. It has had a glamorous history. It has paid for itself many times over. It has in large measure made America the best fed nation on earth. It has had a magnificent growth to the point where it is the envy of all the world. It is an example of cooperative effort on the part of many and varied groups and individuals. Through all its history the individual research worker has been the important element that has spelled success. Without the well-trained scientist, with the proverbial inquiring mind and the unselfish expenditure of energy and brain power, working alone or in concert with his fellow scientists to produce a continued stream of new findings, our progress would have been much more costly and much slower indeed.

Agricultural research is big business in this country. An estimate of the funds available from Federal and State appropriations for agricultural research in 1957 amounted to 187 million dollars. About 73 millions of this

were appropriated by Congress to the Department of Agriculture, 30 millions were Federal grant funds apportioned to the States, and 34 millions were appropriated to State experiment stations by their State governments. There are significant amounts of funds from other sources that add to this amount. It is estimated that about 50,000 technically trained men are engaged in doing experimental work in this program. About 15,000 of these are in the U. S. Department of Agriculture. The organization and administration of a program of this size is a huge undertaking. I think that we can feel grateful to those who have had a part in the development of the agricultural research program in America for the wisdom and foresight they have used to create for us who are now participating in this activity the effective organizational set-ups that exist. It is all based on the concept of organizations and individuals working together in a cooperative venture to serve the public by advancing the knowledge of agricultural pursuits. While different agencies, such as the Federal Department of Agriculture, and each of the State experiment stations, have specific duties and responsibilities, Congress dictated and officials determined that the cooperative approach was the wise one.

Agriculture is made up of many different disciplines and interests and is concerned with numerous commodities useful to society. As the agricultural research program developed, the work arranged itself more or less by commodities. Animal husbandry, the study of animal production, is one such group. But even this group has become so large that it is further divided into departments which correspond more or less to the several classes of farm animals. Thus in the Department of Agriculture, as in the State experiment stations, we have organized research groups into departments of animal, dairy, and poultry husbandry. In each such departmental group the research staff requires specialists representing the various biological sciences, such as genetics, animal breeding, nutrition, chemistry, bacteriology, physiology, statistics, husbandry, etc. But animal research involves so many facets that veterinarians, entomologists, engineers, economists, etc., also devote time and effort to animal research problems.

You are all familiar with the organization at your own institution. You may be less familiar with the organization of animal research in the Department of Agriculture. At the risk of possibly boring you, I shall briefly outline our set-up.

The animal research is organized in two divisions, the Animal Husbandry Research Division and the Animal Disease and Parasite Research Division. The Animal Husbandry Division is responsible for research in animal production except for infectious diseases and parasite work, which is done by the Animal Disease and Parasite Research Division, and for various aspects of economics, engineering, and insect problems. Its major area of research, therefore, is concerned with breeding, feeding, and management in the broad

concepts of these activities. The division is one of seven research divisions making up the Farm Research Group under the leadership of Dr. T. C. Byerly, Deputy Administrator, who reports to the Administrator of the Agricultural Research Service, Dr. B. T. Shaw.

The division program is organized in five research branches--Beef Cattle, Dairy Cattle, Poultry, Sheep, Goat and Fur Animal, and Swine. There is a meat research laboratory and two pioneering research laboratories, one for basic research on blood antigens and one for research in basic animal genetics. A statistical service, including consultative and data processing, is available to our staff. These branches are organized into sections according to the type of research in the program. The research program includes work in both the basic and applied fields. In recent years efforts have been made to increase the research in the basic fields. The establishment of the pioneering research laboratories is a case at point. At the same time, the program in each of the branches includes considerable basic research. We estimate that nearly 20 percent of our funds are used for basic research and in my opinion this should be, and it will be, increased gradually in the years ahead. The research staff consists of around 180 well-trained scientists representing all of the biological science disciplines required for animal husbandry research. In addition, some 175 are on the division payroll in varying degrees as cooperative employees, working on cooperative projects with the States.

The division and each of the branch headquarters are located at the Agricultural Research Center at Beltsville, Maryland. A major part of the program is carried on there. The division also maintains 22 field locations in various parts of the country where research with different classes of livestock is pursued in cooperation with the State experiment stations in the State or region where each is located. In addition, each branch supports cooperative projects of one kind or another at State experiment stations. Such cooperative relations are maintained with all 48 States, Hawaii, Puerto Rico, and Alaska. The division cooperates with State experiment stations in 10 regional research projects, one of which is the W-1 Western Regional Beef Cattle Breeding Project.

The research program of the division is described in some 300 individual line projects. Suggestions for research projects that become a part of the program come from many sources. Division scientists are urged to propose research projects on problems that they feel will contribute needed information. Frequently, suggestions come from people in State stations or from committees such as yours, and from the industry. In addition, the Department maintains Research Advisory Committees which are authorized by Congress, made up of prominent men in various segments of the livestock industries, that meet once a year to advise with the Animal Husbandry Division and other agencies of the Department on its research program relating to livestock. These committees review research proposals made by the Department workers and those from other sources and give the Department

their judgment as to the ones they feel are the most important. The committees' recommendations, and those from other sources, are given serious consideration by the division and branches when new lines of work are initiated.

We consider that the individual research worker is by all odds the most important element in the entire program. While there is opportunity for individual independent research, we encourage the team approach in most of the research effort. We believe that the contribution of different scientific disciplines that specialists bring to bear on a common problem represents the best use of scientific manpower.

It is the desire of the administration to create as good an environment as possible for independent thought and research activity by these scientists. When projects are initiated, following joint planning by the scientists and the supervising officers, the research personnel is given the responsibility, within the limits of available funds, for initiating the research, producing, summarizing, analyzing, and publishing the results.

Administrative officers, including the branch chiefs, the division director and his associates, are available for consultation at all times on problems regarding policy, technical, and administrative matters that inevitably go along with any organization of the size and kind of this division.

One of the major concerns we constantly deal with is financing the research projects. I think it is not unusual that we seem to never have enough funds to do all the work our research workers feel should be done. The cost of things that go into the research effort seems to continually increase and this requires that a continuous review of the projects goes on. We have a project turnover of about 15 to 20 percent each year.

The high cost of research requires all of us to make sure that available funds are wisely utilized on the highest priority projects. It also requires that, with going projects, funds be used for the most essential things. Projects should not be carried on longer than absolutely necessary and care should be taken to make sure that unnecessary duplication of effort and of research is avoided. When proposing or taking up a new project we must be certain that it is the most important needed piece of work to advance our knowledge of the subject in question. At the same time we must recognize that certain types of duplication or replication of research are necessary. We also frequently need to re-do areas of work as improved techniques and new laboratory equipment become available that will enable us to do a better or a more complete job. In this regard I want to refer to the development and almost universal adoption of statistics in animal husbandry research. Coupled with this is the development and use of high-speed data processing equipment which makes it possible to handle and analyze large volumes of data quickly and effectively. These tools have greatly improved

design and layouts of experiments so that significant results can be arrived at in the fastest possible time and with the least possible number of animals, thus reducing the cost of research. Likewise, many new kinds of laboratory equipment for genetic, chemical, and physiological research have made the research task easier and more effective.

One of the most important advancements in our agricultural and animal husbandry research program is the concept of regional research. With the Research and Marketing Act of 1946, the Congress authorized and provided funds to undertake research on agricultural problems that are regional or national in scope. This enabled the Department and the State experiment stations to measurably expand cooperative research and to more completely extend the cooperative work across State lines. It brought forward more completely the concept of pooling technical knowledge, funds, and facilities in a coordinated effort to attack basic and applied problems in a broad and effective way. Thus, the Department and the State experiment stations in the various regions have joined together in pursuing research in a number of regional research projects. Your W-1 project is a good example of one such project. When setting up the regional projects, provision was made for the establishment and operation of technical committees under the guidance of experiment station advisors. This committee arrangement, I feel, is one of the most important features of the program. The deliberations of this committee at its annual meeting here at Tucson are a good example of how important these committees are to a regional research project.

Many of the regional projects provide for a coordinator to work with the Department and various local station workers and to coordinate the activities of all participants in a regional project. Frequently, the coordinator is a USDA man, as in the case with the W-1 project. We are very happy that we are able to participate in the regional projects in this fashion, in addition to lending direct support to a number of the individual State projects.

Research in breeding to improve farm animals is a natural subject for the regional approach. Seven regional breeding research projects with all classes of farm animals are presently in operation. I am sure that we are making much greater progress than if each station and the Department were going their own independent ways in breeding research. As committees like yours operate, there is effective coordination of effort, avoidance of duplication, and agreement on the most important studies that should be undertaken. These things are accomplished by the specialists who are doing the work and who are in the best position to know what should be done and how it should be done. Yet, within the framework of the regional research project there is ample room for individual initiative and expression.

I am sure that we are all conscious of the presence of an increase in the amount of administration involved in the research program. This is inevitable as the size of the job and the size of the organizations increase.

Funds and other things that go into research must be accounted for, staff recruitment, guidance, and servicing must be provided for, reports and publications must be documented, and a variety of other things must be done to service the research worker. The need for adequate support must continually be brought to the attention of the appropriating bodies and the public. These are major jobs and require time and effort and such tasks become the major responsibility of the research administrator. I am sure that the objective of most research administrators is to perform these tasks in harmony with, and to the satisfaction of, the research worker. He wants to accomplish these tasks with as little interference as possible in the work of the research worker because he knows that the success of the entire research program depends on the accomplishments of the man and the team of men actually doing the research job.

You men, as you deliberate here at this meeting and in your work on the coordinated projects at your respective stations, have an important job to perform. Yours is the responsibility of developing facts regarding breeding principles which will be useful to the breeders and raisers of beef in developing more efficient beef cattle. You have an added responsibility for developing some of the material that will find its way into the germ plasm make-up of the future breeding herds. You must be constantly conscious of the need for developing animals that are more efficient producers of meat and that produce carcasses that yield meat cuts in keeping with the desires and demands of the consumers. These animals need to be large users of roughage, fast growers, efficient reproducers, and disease resistant. This is a challenge that I am sure will keep you occupied for some years to come.

In closing I want to read the following two paragraphs which I came across in my reading a short time ago. I give this to you to encourage you in your present task.

"The subject of inheritance is wonderful. When a new character arises, whatever its nature may be, it generally tends to be inherited, at least in a temporary and sometimes in a most persistent manner. What can be more wonderful than that some trifling peculiarity, not primordially attached to the species, should be transmitted through the male or female sexual cells, which are so minute as not to be visible to the naked eye, and afterwards through the incessant changes of a long course of development, undergone either in the womb or in the egg, ultimately appear in the offspring when mature, or even when quite old, as in the case of certain diseases? Or again, what can be more wonderful than the well-ascertained fact that the minute ovule of a good milking cow will produce a male, from whom a cell, in union with an ovule, will produce a female, and she, when mature, will have large mammary glands, yielding an abundant supply of milk, and even milk of a particular quality? ...

".... In fact, the whole art of breeding, from which such great results have been attained during the present century, depends on the inheritance of each small detail of structure. But inheritance is not certain; for if it were, the breeder's art would be reduced to a certainty, and there would be little scope left for that wonderful skill and perseverance shown by the men who have left an enduring monument of their success in the present state of our domesticated animals."

So stated Charles Darwin in his book, "The Variation of Animals and Plants under Domestication", Vol. 1, p. 435-6, 1900.

W-1 Workshop
Tucson, Arizona
July 7 - 10, 1958

FUTURE DEVELOPMENTS IN BEEF CATTLE BREEDING RESEARCH

E. J. Warwick
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In attempting to discuss a situation such as this, I want it clearly understood that I make no pretense of owning a crystal ball. The remarks that I make must be considered as just one person's guesses or opinions which are, I suppose, inevitably tempered by my ideas on the things I think should happen. Also, in discussing a situation such as this, it is almost impossible to separate research and industry developments. Almost inevitably one will influence the other.

The following is a brief summary in outline form of developments which I feel are likely in the future, so far as beef cattle breeding research is concerned.

I. Increased Emphasis on Breeding for Performance

This is inevitable in my opinion, as the need for increased efficiency will force it. It is probable that it will take many turns. It seems likely to me that there will be increased emphasis in research on breeding for performance under specific conditions and/or for specific purposes.

It is likely that we will develop better definitions of performance, and that increased emphasis will be put on developing better methods of measuring performance both for research purposes and for use in the industry.

As part of breeding for performance, I think we will be putting an increased amount of emphasis on performance of the cow. This will include research on how heredity influences the reproductive process as well as how heredity of both cow and calf influences the preweaning performance of calves. We will be forced to obtain more precise knowledge of maintenance requirements of cows and how it varies between cows inherently capable of raising calves differing widely in weight.

To date, we have tended to assume that efficiency of production may be attained most easily through breeding bigger cattle. It seems likely to me that bigger and bigger cattle may not be the complete answer, and that differences in inherent efficiency among cattle with the same inherent growth rates and mature sizes will get more attention.

Also under the heading of breeding for performance, I believe we will breed more for various aspects of carcass quality. This field is, of course, just opening up and the first big job is to define what we mean by superior carcass qualities. Inevitably, I believe we will do a great deal of research on the development of indirect indices or measurements of potential carcass quality. This is almost essential if we are to breed successfully for these things.

In breeding for performance, I believe we will set up more selection experiments to determine genetic parameters with cattle. Many of these selection experiments will doubtless be selection for one item in performance in order that correlated responses may be observed.

II. Uses of Hybrid Vigor

First, we must obtain knowledge of its importance in relation to all aspects of performance including reproductive traits, growth rate, efficiency, and longevity. Then, if the experiments indicate that heterosis is an important factor in any or all of these production traits, we must conduct research in order to learn how to use it most effectively. Will this be through the use of wide crosses for commercial production or will we use it most effectively through the formation of new breeds which will combine the desirable characteristic of both parent stocks?

III. Appraisal of Existing Lines and Strains

It is my prediction that this phase of research will come in for increased emphasis, particularly in the near future. The ingenuity of research workers will be taxed to accomplish the needed research in this field. How much of it can be accomplished through cooperation with breeders rather than on experiment station facilities is one of the questions which must be answered.

IV. How to Use Outstanding Strains for Influencing the Industry

This will inevitably involve increased research in the field of artificial insemination and on the reproductive process itself. Originally, most of us felt that the greatest contribution to be made from the regional beef cattle breeding projects was through development of methods which could be applied by breeders. Recent developments in the artificial insemination field make it seem probable, or perhaps I should say possible, that we can also make a considerable potential contribution through the wide utilization of strains which prove to be superior in performance.

V. Ways and Means of Making More and Better Beef from Dairy Animals

It may sound like heresy to mention this, but I believe research work will be done on this in the future and that, as time goes on, and population

becomes denser, we will make better use of dairy by-product animals in supplementing the nation's beef supply.

VI. Thinking Will Be Less Fettered by Tradition

Whether we will admit it or not, I believe most of us a dozen years ago were inclined to design our research pretty much in line with what we thought there might be a possibility of the industry adopting. Today, developments have taken place in so many fields indicating that the industry will find ways and means of adopting new procedures, if they have real merit from a production standpoint, that I believe our thinking is becoming much freer and we are much more inclined than previously to embark on uncharted courses to see what the possibilities are. I predict that this tendency will increase greatly in the future, and that more and more our research people will be concerned with developing new and fresh ideas rather than replotting old fields.

After giving some of my predictions on things that may come to pass in the future, I think you'll all realize that I have made no shocking, or even especially original predictions. This is, I believe, natural since my thinking and the thinking of all of you is to a large extent circumscribed by what we can see. Most of you, had you been called upon to give a similar talk, would undoubtedly have said things very much in line with the things I have mentioned. In thinking of predicting the future, I would like to quote a sentence I ran across recently in an article by Mr. C. F. Kettering who was discussing the automobile industry. He said, "We have learned a lot in the last half century, the most important being that it is futile to try to predict the future." I imagine that this is equally true of the beef cattle breeding field. Therefore, in all probability I was foolish to attempt to discuss this topic.

However, one sobering prediction is possible and with it there can be no disagreement. In any research which takes as long a period of time to get results as is the case with beef cattle breeding research, it is inevitable that personnel will change. I was interested a few days ago in looking through the 1936 U. S. Department of Agriculture Yearbook to note seventy different State and Federal workers listed as being involved in beef cattle research. Today, twenty-two years later, only ten of these seventy men are still active in beef cattle research and even a few of these ten have gotten into administrative work where their contributions to the actual research field are limited. I suppose there is no reason to suspect that twenty-two years from now much over 15 percent of this group will still be active in this field. A second prediction is related to this, namely, that new personnel will have new ideas. Further, their new ideas will stimulate new thinking of those of us who may be fortunate enough to be around for an extended period.

W-1 Workshop
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INTEGRATING BASIC BIOLOGICAL PRINCIPLES IN
GENETIC RESEARCH WITH APPLICATIONS TO BEEF CATTLE

P. W. Gregory
University of California

Even though it may be familiar to all of you, it seems advisable to review briefly some of the history and developments that led to the science of genetics. The problem of inheritance commanded the attention of leading biologists of Europe as early as the sixteenth century. In the earlier studies, interest was directed toward the inheritance of the whole organism and little progress was made. Later, when attention was shifted to the inheritance of specific contrasting characteristics, great progress was made. This "break-through" was accomplished by an inquisitive Austrian monk, well trained in botany and mathematics, who studied the inheritance of several contrasting characteristics in garden peas. From these studies he formulated two basic laws of inheritance, the law of segregation and the law of independent assortment. His paper is one of the biological classics of all times. This monk presented his results and conclusions before contemporary biologists, but none were able to comprehend their significance. It is a matter of record that his paper lay unnoticed in the libraries for thirty-five years. In 1900, three independent investigators from three different countries working with three different plants rediscovered the basic laws of inheritance and published their findings. All three recognized that Gregor Mendel had clearly set forth the principles in 1865. By 1900, biologists had developed to the point where they could comprehend the significance of these two basic laws of inheritance.

Outstanding botanists and zoologists in America and in Europe immediately became interested in inheritance. A partial list includes investigators such as Winge, Johannsen, Bateson, Goldschmidt, Nilsson-Ehle, Castle, Morgan, East, and G. A. Shull. It is noteworthy that, with perhaps one or two exceptions, each of these men was already an outstanding biologist and a recognized authority of a specific biological discipline. These leaders agreed that the discipline of genetics should be developed to its utmost limit and that genetics should be integrated with all the other basic disciplines such as anatomy, physiology, embryology, cytology, biochemistry, evolution, mathematics, and others.

The first problem in 1900 was to determine how extensively the two laws of inheritance applied to plants and animals. From these investigations the science of genetics was developed. The progress toward this end is a matter of record.

Near the end of the first decade of this century it became evident that genetics could be used to improve plants and animals economically important to man, and courses in genetics were added to agricultural college curricula. About 1912, land-grant colleges began to establish departments of genetics. The application of genetics has proved to be more successful with plants than with animals. In the application of genetics to improve the yield and quality of corn, the studies were sufficiently basic that corn ranks next to *Drosophila* in providing genetic and cytological principles. It is common knowledge that the application of genetics has completely revolutionized commercial corn production, and has also been employed to improve most of the other agronomic and vegetable crops.

The application of genetics to the improvement of domesticated animals proved to be more difficult. In accounting for this, one must consider the nature of the species to be investigated and the limitations inherent in man himself. The experimental species involved have long life cycles, low fecundity, and high maintenance costs. They are thus regarded universally as unfavorable genetic material. The limitations of man appear to be great in number and of many diverse types. In the second decade, when attempts were made to apply genetics to domesticated animals, two types of investigators had to collaborate. First were the geneticists, who knew the latest advances of the times and were well trained in the basic disciplines of biology but often failed to appreciate problems of practical husbandry. The second were the practical husbandmen, who failed to appreciate fully the implications and principles of inheritance and were not sufficiently trained in the disciplines of basic biology. They doubted that the new science of genetics would be as efficacious as the empirical methods of selection that had been handed down by primitive herdsmen. They were reluctant to embark upon genetic programs. Thus, a babel of tongues existed and, unfortunately, still persists to a sufficient extent to handicap the research that is necessary to resolve some of our most important problems.

Practical husbandmen expressed the opinion that mutants that were common in experimental animals rarely occurred in domesticated farm animals, and those that did occur were not concerned with vigor, conformation, yield, fecundity, or other practical problems. They thought it was a waste of time and money to study mutants in the larger mammals. The opinion of the practical husbandman was that the study of the specific gene had little or no place in the improvement of the larger farm mammals.

Late in the second decade and early in the third, geneticists under the leadership of Wright, Fisher, Haldane, and others developed a genetic approach that was more acceptable to practical husbandmen and upon which most of our applied genetic programs are based. This is an indirect approach and is less well adapted to genes that have obvious qualitative effects that can be consistently recognized.

During the past twenty-five years genetic studies have revealed that our domestic farm animals, and especially cattle, harbor innumerable deleterious genes that condition abnormal morphological forms. Many of these are lethal. There are other lethal and deleterious genes more difficult to recognize which condition general infertility, male infertility, female infertility, and prolonged gestation, to mention a few.

It is evident that if the full possibilities of applied genetics programs are to be realized, more use must be made of the basic disciplines of biology for analyzing the stocks at our disposal and the favorable and deleterious genes they possess. Furthermore, a complete integration of the knowledge gained from these disciplines will afford the maximum amount of information that can be used to recognize, differentiate, and evaluate these stocks with respect to their biological and economic fitness. Too often, breeders and investigators fail to realize until great damage has been done that ideal animals for slaughter may suffer numerous genetic and biological deficiencies that render them unfit for sires and dams. It should be the aim and task of the investigator to develop diagnostic techniques that would enable investigators and breeders to recognize such deficiencies early in the life of the individual.

Up to the present time it seems that most investigators applying genetics to cattle have depended too much upon empirical subjective techniques adapted by industry to assay the biological characteristics of their stocks. Even though these techniques serve industry well, they lack the precision that the disciplines of science afford for measuring small qualitative and quantitative differences that characterize specific stocks. It is essential to employ the established biological disciplines to obtain the exactness necessary to adequately measure definitive characteristics of specific populations. If this is the approach, it is then possible to integrate the knowledge from these diverse disciplines to provide the maximum amount of information concerning the stocks under investigation.

My objective here is an illustration of the scope of research of our group and how research from many disciplines can be brought to bear upon a specific problem. Thus, it should be clearly understood this is not a review of the literature, but rather a summary of some of our efforts to resolve the problem of dwarfism.

In addition to body weight, extensive use is being made of several body measurements. These have been obtained from animals born during the decade of 1920 up to the present time, a period of more than thirty-five years. These measurements can be used to show how selection has changed the population during this period. The use of body measurements also enables the investigator to separate different phenotypes and genetic stocks. Thus, it is possible to correlate body measurements with specific phenotypes and genotypes and gene substitutions that may have occurred during

the past three and one-half decades. The accompanying slides summarize briefly the size differences in populations and their relationship to the incidence of dwarfism. The details of this study and others that will be presented here will have to await scientific publication.

The intensive use of anatomy employed by my colleagues in the School of Veterinary Medicine has proved to be most profitable. We now have over six hundred skeletons complete with case histories. The first study (Julian, Tyler, Hage, and Gregory, 1957) proved that the brachycephalic dwarf manifests a premature fusion of the spheno-occipital synchondrosis, thus indicating that the deficiency is achondroplasia. The time of fusion, between birth and five and one-half months of age, of the S-O synchondrosis can be used for identifying this type of dwarf. These investigators have now found that the same stocks that produce brachycephalic dwarfs also produce other segregates subnormal in size and in which the spheno-occipital synchondrosis closes between ten and eighteen months of age. They are thus intermediate between the closure time of the brachycephalic dwarf and the normal closure time of from twenty-four to thirty-six months of age.

The analysis of the appendicular skeleton (Tyler, Julian, and Gregory, 1957) indicates that all of the long bones in the brachycephalic dwarf are shortened but that there is no diminution in diameter. The diaphysis is reduced but the epiphysis is not reduced, thus indicating that the primary centers of ossification are affected. This has embryological implications which affect mesenchyme and cartilage formation. Time will not permit further expansion of these deficiencies upon embryological and fetal development. From these relationships it is possible to develop several indices for differentiating the brachycephalic dwarf from other populations. The study showed that the greatest effect is upon the metacarpal bones. It also indicated that the condition occurs in utero and that hypoplastic achondroplasia is the cause of the dwarfing process. These investigators have further refined the technique for measuring the metacarpal bones, and as a result, diagnosis is more effective. Radiograms are being used in an effort to extend and exploit anatomical differences which occur in the metacarpal of living animals.

As the genetic and anatomical studies progressed, it became increasingly evident that many phenotypic forms subnormal in size are involved, and that dwarfism is a complex of several phenotypes subnormal in size rather than a single component. Several different hereditary forms of dwarfs had been recognized previously and these forms and the complications which might arise in progeny testing were discussed in considerable detail (Gregory, Roubicek, Carroll, Stratton, and Hilston, 1953).

Within recent months three additional diagnostic criteria have been discovered and developed. These are useful in separating the different members of the dwarf complex. The first criterion is the quantitative

measurement of internal hydrocephalus of the lateral ventricles (Julian, 1956, unpublished). The other two criteria are processes that project into the cranial cavity, one being the cartilaginous wings of the orbito-sphenoid (WOS), and the other an enlargement of the posterior intra-occipital synchondrosis (PIOS), (Tyler, Julian, McFarland, Evans, and Gregory, manuscript).

We have evidence that when the WOS and the PIOS projections are extremely large they exert pressure upon the cerebrum and cerebellum, respectively. This can account for the paralysis that may be observed and much of the incoordination that commonly occurs in brachycephalic dwarfs and other components of the dwarf complex. The "stupid" condition manifested by certain components of the dwarf complex may also arise from these same pressures (Kennedy and Hughes, 1956, unpublished).

There are still other skeletal parts, the cranium especially, that are yet to be investigated. We believe that many other diagnostic skeletal characteristics are yet to be discovered that will serve to differentiate members of the dwarf complex and normal animals. The diagnostic criteria we now have indicate that the brachycephalic dwarfs which segregate from animals normal in size and those that segregate from compressed animals are phenotypically similar. Critical genetic tests also indicate that these brachycephalic dwarfs from the two different sources are genetically identical. There is also evidence that the diagnostic criteria developed may be useful in determining the relationship of the extreme hydrocephalus condition to the dwarf complex.

The cytochemical and cytological aspects of bovine dwarfism were investigated by Leuchtenberger, Schrader, Hughes-Schrader, and Gregory (1956). They found that the nuclei of brachycephalic dwarfs were deficient in desoxyribosenucleic acid (DNA). This is of utmost biological significance. This reduction was sufficient to warrant checking the chromosome number of dwarfs. Chromosomal analysis revealed that the chromosome number was normal and the reduction in DNA values was not due to alteration in chromosome number.

The blood of the brachycephalic dwarf was subjected to a series of chemical and hematological studies. Both the cholesterol and the protein-bound iodine values were in the normal range and indicated that the brachycephalic bovine dwarf is not a primary thyroid cretin. Most of the hematological data agree with the normal values established for beef cattle. However, the differential cell count in the dwarf is statistically significant (Cornelius, Tyler and Gregory, 1956).

These investigations are briefly summarized.

1. A study of field data provided by breeders indicates that the brachycephalic dwarf is conditioned by one autosomal recessive gene with complete penetrance. Additional hereditary types subnormal in size, such

as the comprest and other diverse dwarf phenotypes, were evident. It was recognized that many or all of these forms might interfere with progeny testing and this has proved to be the case.

2. Body weights and body measurements have been obtained from four different groups of animals.
 - A. A small sample of normal animals born in the 1920's
 - B. A much larger sample of normal males and females together with their progeny obtained from 1940 to 1952
 - C. Mutant stocks (and their progeny) comprising the comprest type, which is subnormal in size, brachycephalic and dolichocephalic dwarfs, and experimental progeny obtained from these stocks
 - D. Dwarf-carrier cows and their experimental progeny produced under controlled conditions
3. Anatomical studies were made of all the stocks listed above. These studies include:
 - A. The time of closure of the spheno-occipital synchondrosis
 - B. Specific characteristics of the long bones with special emphasis upon the metacarpal bones and several diagnostic criteria developed from specific measurements of these bones
 - C. The cartilagenous wings of the orbito-sphenoid (WOS)
 - D. The enlargement of the posterior intra-occipital synchondrosis (PIOS)
 - E. A quantitative method for measuring internal hydrocephalus
4. The cytochemical and cytological analyses
 - A. The nuclei of brachycephalic dwarfs have proved to be deficient in desoxyribosenucleic acid (DNA), an essential constituent of the nucleus. It was further determined that this diminution of DNA was not associated with the loss of a chromosome since dwarfs have the normal chromosome number.
5. Hematological studies reveal that most of the blood constituents of the brachycephalic dwarf are normal, but that the differential count is statistically significant.

6. Physiological and biological studies under way are extremely promising, but less advanced.

Although they have not been completely analyzed, body measurements may be employed to differentiate most of the mutant and normal stocks under investigation. The anatomical indices developed to date are critical and have clear-cut diagnostic values. The full potential of the anatomical possibilities is yet to be realized. Our research group is unanimous in the opinion that complete integration of genetic, anatomical, cytological, physiological, biochemical, and other disciplines will go far toward resolving the dwarf problem. We are all convinced that the basic information obtained from this study will be of value in the solution of other cattle problems arising from still other genetic and environmental causes. Thus, the opinion prevails among the members of our research group that the development of objective standards in several biological disciplines for measuring diverse cattle populations will eventually prove to be our greatest contribution.

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CARBOHYDRATE METABOLISM IN RUMINANTS

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There are several major points of difference in the carbohydrate metabolism of man and of ruminants. To be emphasized are the differences in basal values of blood glucose, the relative insensitivity of ruminants to insulin, the specific importance of fatty acids, especially propionic, for ruminants, and the apparent independence of appetite in ruminants from blood glucose levels.

Blood Glucose Levels

Man	80 mg. %
Cattle	60 mg. %
Sheep	40 mg. % (Average)
	20-50 mg. % (Range)
	2 mg. % (Carotid-jugular concentration difference)

Role of Glucose in Man (cat, dog, rabbit)

1. Required for glycogen in liver, muscle, central nervous system.
2. Source of aerobic and anaerobic energy of the central nervous system.
3. Importance for citric acid cycle: Main source of pyruvic acid. (Pyruvic acid is main nonprotein source of oxalacetic acid required for continuous operation of the citric acid cycle).
4. Possibly concerned in the regulation of the appetite.

Glucose and the Citric Acid Cycle

The citric acid cycle can be said to commence with the addition of a 2-carbon fragment in acetyl-CoA to the 4-carbon fragment oxaloacetate to form the 6-carbon molecule of citrate. Citric acid in several steps is converted into the 6-carbon isocitric acid, and then by dehydrogenation and decarboxylation to a 5-carbon fragment, through a number of 4-carbon fragments to oxalacetic acid. All steps are reversible except alpha-keto glutaric acid to succinic acid. The irreversibility of this step has the effect of making the cycle irreversible (West and Todd).

As a molecule of oxalacetic acid is produced each time the cycle is completed, the cycle theoretically can be kept in operation by supplying new molecules of oxaloacetate, the molecules of acetyl-CoA being supplied by either fats or carbohydrates.

In practice, however, 4-carbon fragments fail to appear because of

1. the conversion of some alpha-keto-glutaric acid to glutamic acid
2. the conversion of some oxalacetic acid to aspartic acid, and
3. the degradation of the unstable oxalacetic acid to pyruvic acid

Thus, continuously, new 4-carbon fragments have to be supplied to allow repeated recycling. The new fragments must originate from amino acids or from carbohydrate through pyruvic acid. If much comes from amino acids, it means protein breakdown. Thus, a satisfactory growth economy requires that as much as possible of the 4-carbon fragments should come from pyruvic acid by the addition of carbon dioxide, and that as much as possible of the pyruvic acid be of carbohydrate origin.

It must be emphasized the cycle can run on carbohydrate alone, on protein alone, or a mixture of any two or all three of carbohydrates, protein, or fat. But the cycle cannot run on fat alone, and in the absence of protein or carbohydrate source of oxaloacetate, the acetyl-CoA piles up in ketone bodies and ketosis develops.

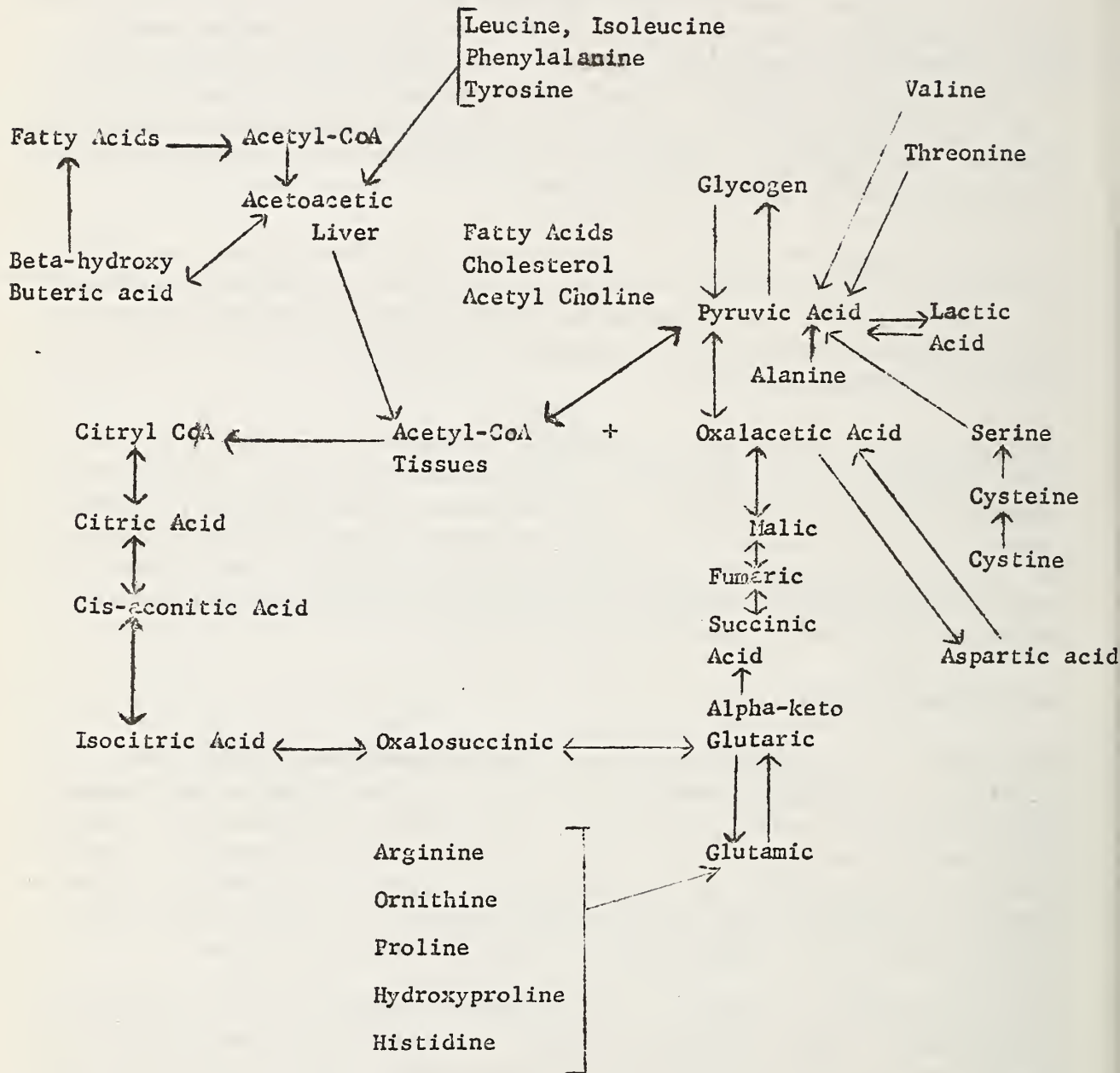
When glucose, via the decarboxylation of two pyruvate fragments and the citric acid cycle, is oxidized to carbon dioxide and water, 38 high energy phosphate bonds are produced. At an estimated 11,500 calories per phosphate bond, this represents an energy recovery of about 437,000 calories. As the heat of combustion of glucose is 686,000 calories, the process of converting the heat of combustion of glucose into high energy phosphate bonds is 64 percent efficient (West and Todd).

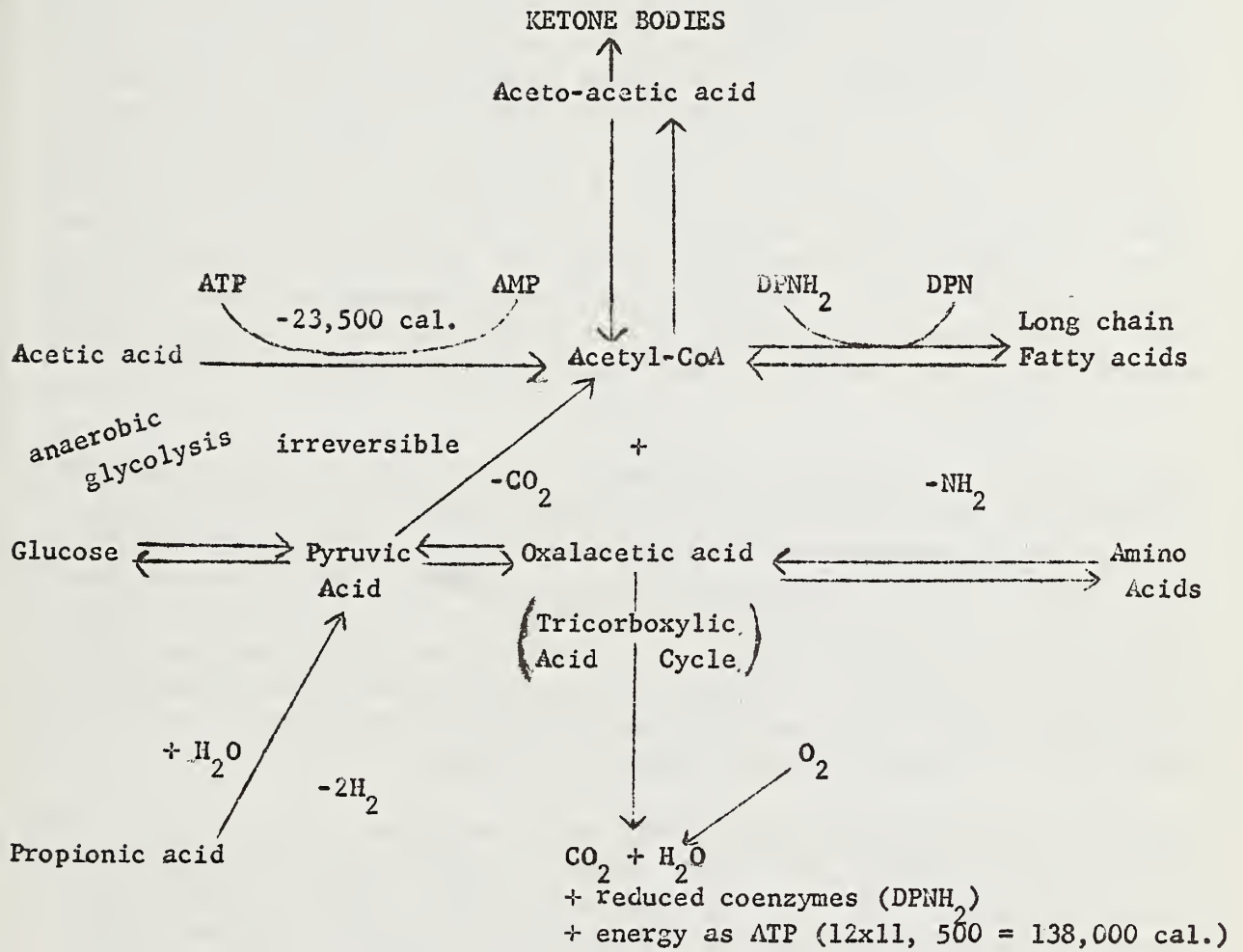
Regulation of Appetite

The control of appetite in man seems closely associated with glucose level of blood. When glucose levels of the blood are low, there is an intense drive toward the eating of food, and when glucose levels are high, appetite may be said to be eased or low. Food intake in man is reduced by the injection of glucagon and is increased by the injection of insulin. Glucagon causes an increase in the levels of blood sugar and insulin reduces the levels of blood sugar (Stunkard, von Ittallie, and Reis, 1955).

The main exception to the rule that glucose governs the level of food intake in man is among the diabetics, in that diabetics have very high blood sugar levels and yet they are almost continuously hungry. For this reason, the theory that the blood glucose levels control appetite in man has been altered to the theory that the controlling factor is glucose utilization as indicated by the difference between arterial and venous levels of glucose (Mayer, 1955).

However, there are several factors which would determine the difference in levels between arterial and venous glucose aside from what might be called





glucose utilization. The first item is blood flow. When blood flow is low, arterial and venous differences will be very high, while if blood flow is high, the arterial and venous differences will be very low. One could easily set up conditions such that the blood flow would be high or low, somewhat independent of appetite. This is particularly true when arm vein and finger capillary blood are used for the determination of the glucose levels.

The simple diffusion of glucose from the blood to the tissues when the difference in glucose levels between blood and tissue is high, would give rise to large arterio-venous differences even though no glucose was being used. Glucose utilization has to be considered a vague term since it involves several things. The conversion of glucose into glycogen is one method of utilization of glucose; the conversion into lactic acid is another; and the conversion to carbon dioxide is a third mechanism of the utilization of glucose. Either the theory has to say that all of these items are equivalent as far as glucose utilization and appetite are concerned; or to be more useful, the theory should define more clearly what is meant by glucose utilization. Then one would be able to correct arterio-venous differences in the direction of giving the glucose utilization figure concerned with the regulation of appetite.

Experiments on mice indicate that appetite is controlled through the hypothalamus, and presumably in the hypothalamus there are some cells which might be called glucose receptors and these react to the level of blood sugar (Mayer, 1955). When blood glucose levels are high, these cells are active and reduce appetite by the inhibition of a "feeding" center. When blood glucose levels are low, they are inactive and induce appetite by releasing this inhibition. If these cells are destroyed either surgically or by the administration of goldthio-glucose, mice are hyperphagic, and accumulate fat and increase in weight beyond the normal.

Goldthio-glucose destroys hypothalamic cells but other gold compounds do not induce hypothalamus lesions. This indicates that the glucose fragment plays a specific role in the action of goldthio-glucose. One may suppose that glucose is specifically fixed and metabolized in special glucose-sensitive neurons; that goldthio-glucose is similarly fixed because of the similarities in structure, but cannot be metabolized; and that the continued presence of gold in relatively high concentrations leads to destruction of the cells where it has accumulated.

Blood Sugar in Sheep

Control values	33-57 mg. percent
After intravenous glucose	255-1480 mg. percent
Control: carotid-jugular glucose difference	3.2 ± 1.8 mg. percent
Arterio-venous difference (after glucose)	6.1-7.7 mg. percent

Sheep are highly resistant to the intravenous injections of insulin. Convulsions are seldom seen, although glucose will drop to levels of 1-3 mg. percent.

Blood Sugar and Appetite in Sheep

To study whether high levels of blood glucose depressed appetite in sheep, 50 percent glucose was given intravenously about 24 hours after withholding feed. One hour later, the same amount of glucose was infused. Single infusions ranged from 100 to 150 ml. Food consumption was measured in the hour immediately following the second injection of glucose. The following data were obtained (Manning, Alexander, and Krueger):

Total Glucose Administered	Food Consumed	Glucose Injected
None: Uninjected controls	1.5(0.5-2.0) lbs.	None
None: Saline injected controls	1.9(1.3-2.4) lbs.	None
1.67 g/Kg	1.8, 2.0 lbs.	100 g.
2.50 g/Kg	2.4, 2.5, 2.3 lbs.	150 g.
4.17 g/Kg	2.4 lbs.	250 g.
8.3 g/Kg	1.2 lbs.	500 g.

Evidently high levels of blood glucose did not decrease food intake in sheep. There may be the possibility that both saline infusions and glucose infusions led to a greater rate of food intake.

Volatile Fatty Acids

	Total mg. percent	Acetic Percent	Propionic Percent	Butyric Percent
Man-Venous	1.8	90	5	5
Cattle-Venous	7-14	93	2.5	2.5
Sheep-Venous	2-10			
Fasted 2 days	1.2			
Fasted 4 days	0.8			

Acetic Acid

Acetic acid is ineffective in relieving insulin hypoglycemia in sheep. Acetic acid is frequently present in concentrations of 12 mg. percent in carotid artery blood and in concentration of 7 mg. percent in jugular vein blood.

When acetic acid is infused intraruminally in fasted sheep, there follows an increased nitrogen excretion in the urine, a decrease in the blood sugar level, an increase in ketone bodies of the blood and urine, a decreased plasma carbon dioxide combining power, and a heat increment equivalent to 41 percent of the heat of combustion of the acetic acid administered (Armstrong and Blaxter, 1957). These sequelae can be explained on the basis

of a lack of available 4-carbon fragments (oxalacetic acid and hence its precursor, pyruvic acid) to insure the rapid degradation of acetate. Part of the requirement is met by the breakdown of protein, and this accounts for the increase in nitrogen excretion; part is met by the utilization of some of the small carbohydrate reserves available in ruminants. Failure to handle all of the acetate by the citric acid cycle leads to acetone bodies in the blood and urine and to a decreased combining carbon dioxide power of plasma.

Propionic Acid

Acetate is converted into aceto-acetate only when insufficient oxaloacetate is available to operate the citric acid cycle. Required for the continued operation of the cycle are either protein, propionic acid, or glucose, to provide pyruvic acid as the precursor of oxalacetic acid. In ruminants, with the exception of the small amount of absorbed glucose all stores of glycogen have their origin in propionic acid or from amino acids yielding a 3-carbon fragment. Thus, propionic acid is a very important metabolite for the conservation of protein in the ruminants.

Propionic acid can be oxidized to pyruvic acid and then pick up carbon dioxide to become oxalacetic acid, or it can pick up carbon dioxide and be converted into succinic acid. Thus, propionic acid may enter the citric acid cycle either as oxalacetic acid or as succinic acid.

Given intravenously, propionic acid relieves insulin hypoglycemia in sheep. The elevation of blood sugar is accompanied by an increase in blood pyruvate and in blood lactate. When infused into the rumen of fasting sheep, propionic acid brings about a decrease in nitrogen excretion, and is not accompanied by the ketosis which occurs after acetic acid infusions. The heat increment of infused propionic acid is only 13 percent of the administered calories as compared with 41 percent after infused acetic acid.

One of the main questions currently of interest in beef cattle research is the question why a slow gainer gains slowly. Could propionate here be a key metabolite in explaining the differences between slow and rapid gainers? Is propionic acid low in slow gainers? If so, amino acids would be required to operate the citric acid cycle, and this would explain the slow rate of gain.

Pregnant Ewe Disease

In late pregnancy of ewes, particularly when twins are carried, there develops ketosis, low blood sugar, increased nitrogen excretion, and general debilitation. The symptoms are relieved by the administration of carbohydrate.

The fetus essentially is a nonruminant and depends upon glucose to operate the citric acid cycle. Blood glucose levels of 100 mg. percent are reported for newborn lambs. As maternal glucose may reach levels as low as 10 mg.

percent during pregnancy, there is a definite problem in chemical dynamics to provide a level of 100 mg. percent in fetal blood. Little is known of the details of carbohydrate metabolism during pregnancy. But propionic acid may also play a key role in pregnant ewe disease because of its position as the only nonamino acid precursor of glucose, and if amino acids are used for citric acid recycling, they will be less readily available for fetal growth.

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APPLICATION OF PAPER CHROMATOGRAPHY
TO BEEF CATTLE BREEDING PROBLEMS

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The animal breeder is vitally concerned with similarities and differences within the species with which he works. He is particularly interested in classifying the animals in the population into categories based on genetic differences. This is not always an easy task. Sometimes the variations for certain characteristics are of such magnitude that phenotypic differences are readily apparent to the eye. Often it is possible to classify a population into a few distinct classes for some characteristics. As the number of observed characteristics increases and/or as refinement of measurement is improved, it is found that variation is much greater than was at first supposed from the gross phenotypic appraisal. Animals that were considered to be normal by gross observation may with the application of more detailed measurements be found to show many variations from other animals that were also considered to be normal. It soon becomes exceedingly difficult to describe the normal condition. Similarly it is very difficult to describe abnormal phenotypes in regard to most characteristics. It is thus very difficult to relate phenotypic differences and similarities to differences and similarities in genetic make-up.

The ways in which genes act in affecting characters are many and varied. Much has been learned in recent years concerning some of the processes involved between the presence of the gene in the new zygote and the developed characteristic in the mature individual. Biochemical genetics is a new and promising field in this area.

Evidence obtained to date suggests that certain genes may control the presence or absence of specific substances. Other genes may control the amount of these substances, while still others may influence the potency. In a few instances the relationship seems to be a simple "one gene, one enzyme" type. In most instances, however, the relationship is much more complicated. The information available strongly indicates, however, that genetic differences are associated with differences in metabolic processes. Differences in metabolic processes are, undoubtedly, much greater than most people have realized. Williams and his co-workers (1951) at Texas have reported studies made with man. The findings show marked differences in taste sensitivity, and salivary constituents as well as urinary constituents. Quantitative and qualitative differences were both found. While these differences have not been studied fully in relation to genetic composition, the implications are strong. Patterns from identical twins were very similar while wide differences were found among patterns obtained from less closely related individuals.

A change in intermediary metabolism may manifest itself in several ways. Among these are

1. the presence of a metabolic substance not usually present
2. the absence of a substance that is generally present
3. a change in concentration or rate of use of a metabolite
4. a change in excretory rate of a metabolic substance, and
5. the appearance of some gross change in the organism

These may, and frequently do, occur in combination.

An excellent example that illustrates the relationship between genetic make-up and accumulation of a metabolic substance is well known in man. Phenylalanine is handled by the cells in several ways. Much of it goes to make up body proteins. Some of it, also, is oxidized to phenylpyruvic acid (by replacing the amino group with oxygen). By successive steps it is then degraded, finally, to carbon dioxide and water. Individuals who suffer from a disease known as phenylketonuria, or phenylpyruvic oligophrenia, are known to excrete considerable amounts of phenylpyruvic acid in the urine. These individuals evidently do not have the ability to oxidize phenylpyruvic acid. Such individuals are mentally deficient. The condition is reported to be a simple recessive.

In studying the manifestation or differences in metabolism it would be very interesting if quantitative measurements of the basic output of the various body secretions could be made. This, however, is not possible because, first, many of these substances are very transitory, second, it is usually impossible to isolate the entire secretion in many cases, and third, because the large number of secretions would make the quantitative and qualitative study of each impracticable. Therefore, methods which will study several metabolites at one time and provide a rapid method of screening for differences are needed. These are the chief virtues of filter paper chromatography.

Paper chromatography is a fairly recently developed research tool that offers much promise of yielding useful information in the study of metabolic patterns in individuals. It is a process by which a small amount of the sample to be studied is placed on a piece of filter paper. The filter paper is then irrigated with a solvent. After a period of time the material will generally be found to have moved from the original point of application. If the material is made up of several substances, it will have separated partially or completely into its components.

Two types of paper chromatography are commonly used--one-dimensional and two-dimensional. In the one-dimensional type, strips of filter paper are generally used. A small quantity of the material under study is placed on

this paper a few centimeters from one end and dried. The strip is then suspended in the solvent. The ascending or descending method may then be used to produce a chromatogram. In the ascending method the solvent moves by capillary action against gravity, while in the descending method the solvent moves with gravity.

In two-dimensional separation the material to be studied is placed near one corner of a sheet of filter paper. Separation is first made in one direction with one solvent. After drying the chromatogram, separation is made at right angles with another solvent.

Two-dimensional has the advantage of more effectively separating compounds that are too closely grouped together after one-dimensional separation. In other words, two substances may move about the same distance in solvent A. In solvent B, however, their rate of movement may be quite different. They would be separated effectively in the two-dimensional exposure using solvents A and B.

The common practice is to remove the filter paper from the solvent before or immediately after the solvent front has reached the edge of the paper.

Interpretation of Chromatograms

After the chromatogram has been made it is necessary to apply some technique to make the differences and similarities discernible. A common practice is to inspect the chromatogram under exposure to ultra-violet light or to apply color developing reagents. Ninhydrin reagent (triketohydrindene hydrate) is widely used, but many others are effective for specific substances.

The color, intensity and purity of color, size, and position of the spots are the main items that reveal information concerning the sample.

Identity of a particular spot on a chromatogram is not always easy. In the simplest cases the chromatogram made from the sample is compared with a chromatogram made (usually at the same time) from known standards. Difficulties frequently arise, however, in interpreting chromatograms from biological fluids because biological fluids are not simple mixtures and mixtures often affect the movement of a substance on a chromatogram.

Color of the spots under different developing reagents is helpful in describing the chromatogram and is helpful in identifying the substance. Ninhydrin is particularly useful in the study of amino acids.

The relative positions are expressed in R_f values. This value expresses the relationship between distance from the starting point to the spot as compared to the distance from the starting point to the solvent front position.

Spot size is indicative of the amount of substance present within limits.

Application to Beef Cattle Breeding

To illustrate in a small way how paper chromatography might be applied to a breeding problem, I would like to review some of the work done at our station. I realize that this would be a better illustration if the study had given information which had fully solved the problem; which, however, it did not. Nevertheless, useful information was obtained and it will serve to illustrate how this technique may be utilized.

At the Utah station studies were made utilizing paper chromatography concerning the dwarf condition in cattle. The first substances studied were the amino acids. Whole blood, blood serum, and urine were used. Chromatograms developed from urine, when compared to chromatogram standards made from amino acids, suggested that there was more glutamic acid in the urine of the "snorter" dwarfs than in the urine of normal animals. Microbiological assays were then made on urine samples collected over a 24-hour period. These assays bore out the earlier supposition that the dwarfs did excrete more glutamic acid. When expressed in relation to creatinine, the differences were pronounced. The values were as follows:

Creatinine/Glutamic Acid Ratios

	24-hour Sample		67 Single Samples	
	Range	Average	Range	Average
Dwarfs	1.2 - 1.8	1.5	1.1 - 2.1	1.6
Normal	3.0 - 12.8	5.0	3.0 - 14.7	7.4

There was no overlap. Age did have a strong influence. The ratios in the 3.0 - 4.0 range in the normals were found only in calves. No difference was detected between known carriers and those thought to be noncarriers.

Studies were then initiated to determine if substances might be found which could separate carriers and noncarriers. Six different solvents were studied in detail and the chromatograms were developed with several reagents and also studied under ultra-violet light. Whole blood, blood serum, and urine were studied. These early studies indicated that more differences appeared in chromatograms made from urine than from the blood, and the substances in the urine were more easily separated. More spots appeared in the chromatograms made from urine when observed under ultra-violet light than when developed with ninhydrin. A solvent mixture of propanal-ammonia seemed to give best results.

Creatinine was chosen as the base to which the amount of urine to be placed on the chromatogram was determined. While not a perfect base, it did appear to be a satisfactory working base.

Large numbers of chromatograms were then made from dwarfs, carriers, and noncarriers. These were studied in detail. Presence and absence of spots, Rf value, and shape, size, and color of the spots were included in this study.

Chromatograms from dwarfs had, in general, the greatest total number of spots, but there were exceptions. The main interest was in the carriers and noncarriers. The "14" spot showed differences for these groups. It was present in the noncarriers and absent in carriers, with few exceptions.

Because the 14 spot showed some promise of being related to dwarfism, it was given further attention. Urine was concentrated by evaporation in vacuo and urine equivalent to an original volume of 3 ml. was made into a chromatogram. The 14 spot was present in all such samples from both carriers and noncarriers. This indicated that the differences associated with the 14 spot were quantitative rather than qualitative.

Urine was next extracted with a number of solvents, concentrated, and chromatograms made. Three of the solvents seemed to remove the 14 spot completely. Benzene removed the 14 spot with very little other material that showed up in the chromatogram. Ether extraction showed fluorescence in both the ether solution and the extracted urine, indicating that the spot is made up of more than one compound.

Forty cc. of urine were then extracted with benzene and the extract evaporated to 0.5 ml. All of this was spotted on the filter paper and made into a chromatogram. This gave a new pattern with three spots in the general area of the original 14 spot. The explanation for this is not yet known. While it suggests that three substances may be involved and are showing up only upon greater concentration, it is not proof. There is a definite possibility that only one or two substances are involved but something in the solution is causing a multiple Rf value.

Detailed studies have been made of the substance concentrated in the 14 spot area. Solubility tests and results of tests with reagents suggest that the substances are apparently steroid in nature but as yet they are unidentified. If they can be identified, and if suitable quantitative tests can be devised, their value for identifying genotypes can be determined.

These examples illustrate to some extent the way paper chromatography may provide leads for other related chemical studies. As an exploratory tool it was very useful. Many other possibilities that are worthy of study in relation to this breeding problem have been suggested by the results

obtained with chromatography. Only a small percentage of the possible tests that could be made with chromatography in relation to genotypes in cattle have been made. The use of chromatography as a quantitative measure of the material in the 14 spot is well worthy of consideration if other suitable quantitative measures are not developed. Other promising solvents and developing reagents, as well as the study of animals subjected to various types of stress, are worthy of attention. These are only a few of the possibilities that might be investigated.

In Summary

Chromatography is a useful tool for screening animals for differences in metabolic processes. It is appealing to the geneticist in that it is getting back somewhat closer in its measurements to the cause of the difference than do many other phenotypic measurements, such as body size, or skeletal shape relationships. The field associated with the application of chromatography to the genetics of large animals is largely unexplored. The possibilities are great. Many suitable solvents and developing agents are now known and many more can undoubtedly be developed. To the biochemist and the geneticist with imagination it offers great promise.

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ESTIMATION OF VARIANCE COMPONENTS

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Since the partitioning of variances was introduced by R. A. Fisher in the analysis of variance, continued extension and application of the techniques have been utilized in an effort to measure the variability of various attributes of interest in biological populations. Much of the attention recently has been devoted to variance components, with the result that the theory and its mathematical amplification has left most research workers in a cloud of confusion. Extensive use of this technique is made in many fields without a full understanding of the assumptions required to produce unbiased estimates of these components or realization of the limitations on the use of the results. Fortunately, the assumptions underlying the analysis of variance and the related measurements can stand considerable bending without giving erroneous results within the tolerances of most experiments. Nevertheless, it would be desirable to review some of the basic foundations of the analysis of variance and the derivation of the variance components before discussing the use of the results in heritability estimates.

We are all aware that variation is a characteristic of measurements of even the most homogeneous populations. Such variation is attributable to chance or random influence of environmental effects on individuals. These environmental contributions include variation in the use of measuring devices, human error, and other changing conditions. A convenient method of representing such measurements is with a simple model or equation

$$Y_i = \mu + e_i$$

where Y_i is the observed value, μ is the true value, and e_i the error of observation for the i^{th} item. Here we make our first assumption that the e_i 's are independent. If in fact the errors are not independent, such as the situation in which fatigue causes the successive errors to increase or we tend subjectively to "correct" by making adjustments in alternating values, then the resulting variances will be biased. In sampling a population, if we select the individuals such that the probability of selection is equal for all individuals at any given time, which is called a random process of sampling, this random sample will be free of any tendency for errors in successive observations to be related. Now, rewriting the first equation as

$$Y_i - \mu = e_i$$

we note that these errors are deviations of the individual values from the true value and we may imagine that the average of all such deviations will tend to zero if in fact the errors are independent. Since the average will tend to the same value for any population, it is necessary that we adopt some other measure of variation, for which we conveniently choose the average of the squares of the errors

$$\sigma^2 = \frac{1}{N} \sum_i e_i^2 = \frac{\sum_i (Y_i - \mu)^2}{N}$$

We know the values for the population cannot be obtained with any biological population, so we must base the estimates of the parameters on sample statistics. Hence, we have

$$\frac{\sum_i Y_i}{n} = \bar{y} \quad , \quad \frac{\sum_i (Y_i - \bar{y})^2}{n - 1} = s^2$$

The division by $(n - 1)$ in computing s^2 is necessary to provide an unbiased estimate of σ^2 (i.e., the average of all such values of s^2 will be σ^2) where the sample size is n . As an illustration, if we select 20 calves from a large herd at random and obtain the weights as follows:

<u>Y</u>	<u>Y-$\bar{y}$</u>	<u>Y</u>	<u>Y-$\bar{y}$</u>	<u>Y</u>	<u>Y-$\bar{y}$</u>	<u>Y</u>	<u>Y-$\bar{y}$</u>
297	-29	313	-13	325	-1	340	+14
301	-25	316	-10	327	+1	345	+19
304	-22	318	- 8	328	+2	356	+30
309	-17	319	- 7	332	+6	357	+31
311	-15	322	- 4	336	+10	364	+38
							<u>0</u>

then

$$\sum_i Y_i = 6520 \quad , \quad \sum_i (Y_i - \bar{y})^2 = 6866$$

$$\bar{y} = \frac{6520}{20} = 326 \quad \text{and} \quad s^2 = \frac{6866}{19} = 361.4$$

If we now divide the original 20 values into two groups at random as follows:

I		II	
Y_1	$Y_1 - \bar{y}_1$	Y_2	$Y_2 - \bar{y}_2$
304	-19.7	297	-31.3
311	-12.7	301	-27.3
313	-10.7	309	-19.3
316	- 7.7	318	-10.3
319	- 4.7	325	- 3.3
322	- 1.7	332	+ 3.7
327	+ 3.3	336	+ 7.7
328	+ 4.3	345	+16.7
340	+16.3	356	+27.7
357	+33.3	364	+35.7
	<u>0</u>		<u>0</u>

and we repeat the calculations for each group separately, we have

$$\begin{aligned}\bar{y}_1 &= 323.7 & \bar{y}_2 &= 328.3 \\ \sum_i (Y_{i1} - \bar{y}_1)^2 &= 2152.1 & \sum_i (Y_{i2} - \bar{y}_2)^2 &= 4608.1 \\ s_1^2 &= 239.1 & s_2^2 &= 512.0\end{aligned}$$

and we note the small difference in mean values and the larger difference between the variances. If we now note the sum of squares for the two groups as

$$2152.1 + 4608.1 = 6760.2$$

we find a discrepancy of

$$6866.0 - 6760.2 = 105.8$$

between the sums of squares for the two examples. Coincidentally, if we compute

$$K_1 (\bar{y}_1 - \bar{y})^2 + K_2 (\bar{y}_2 - \bar{y})^2 = 10(323.7 - 326)^2 + 10(328.3 - 326)^2 = 105.8$$

we find the discrepancy is then the deviation of the group means from the over-all mean. Now, we may observe the individual values can be characterized by a model

$$Y_{ij} = \mu + G_i + e_{ij} \quad \text{or} \quad Y_{ij} - \mu = G_i + e_{ij}$$

where G_i represents effect or difference for the i^{th} group $(\bar{y}_i - \bar{y})$ and e_{ij} the random error of the j^{th} individual in the i^{th} group.

$$G_1 = 323.7 - 326 = -2.3$$

$$G_2 = 328.3 - 326 = +2.3$$

and from this we have

$$\sum_i \sum_j (Y_{ij} - \mu)^2 = \sum_i \sum_j (G_i + e_{ij})^2 = K \sum_i G_i^2 + \sum_i \sum_j e_{ij}^2 + 2K \sum_i G_i \sum_j e_{ij}$$

Since we selected the individuals for the two groups at random, $(\sum_j e_{ij} = 0)$, which may be easily verified by summing the deviations within each group, then

$$\sum_i \sum_j (Y_{ij} - \mu)^2 = K \sum_i (\bar{y}_i - \bar{y})^2 + \sum_i \sum_j (Y_{ij} - \bar{y}_i)^2$$

which we label as total sum of squares between groups, and within groups, respectively, where

$$G_i = (\bar{y}_i - \bar{y}) \quad \text{and} \quad e_{ij} = (Y_{ij} - \bar{y}_i)$$

which is presented in the analysis of variance as follows:

	Degrees of Freedom	Sums of Squares	Mean Square
Between groups	1	105.8	105.8
Within groups	18	6760.2	375.6
Total	19	6866.0	361.4

The mean squares, obtained by dividing the sum of squares by degrees of freedom, are the variances for the respective effects. While the sum of squares and degrees of freedom are additive, the mean squares are not.

We must remember that the selection of the two groups was at random from a single group, so we would expect on the average the between-group mean square to be similar to the within-group mean square. Upon repeated sampling of the same values we would find the ratio of these mean squares would tend to follow a pattern which is generalized by the F distribution.

Now, imagine that all the animals in Group I were from one sire and those in the second from another sire and the weights for animals in Group II were all 10 pounds greater due to the influence of the sire on weight. We would then have

$$\bar{y}_1 = 323.7, \quad \bar{y}_2 = 338.3, \quad \text{and} \quad \bar{y} = 331$$

as the respective means. We can see $s_1^2 = 239.1$ is unchanged and can show $s_2^2 = 512.0$ is unaffected by the increase in weight, but the combined variance $s^2 = 411.9$ is larger than before. Then the difference in sum of squares

$$7826.0 - (2152.1 + 4608.1) = 1065.8$$

is as before

$$10(323.7 - 331)^2 + 10(338.3 - 331)^2 = 1065.8$$

and

	d.f.	S.S.	M.S.
Between sires	1	1065.8	1065.8
Within-sire groups	18	6760.2	375.6
Total	19	7826.	411.9

We have made an additional assumption of homogeneity of variances, which implies that the variability among progeny is essentially the same for both sires. If this is not true, then both tests of significance and confidence intervals may be seriously disturbed. This, in fact, can be a real problem when data on several sires are collected over a period of years and no adjustment is made for the sire $\times$ year interaction.

In the analysis of variance we note the between-sire mean square is considerably larger than the previous between-group mean square. Since the original values were retained to the extent that the within-group variance was unchanged, then the increase in mean square can be due only to the

added value of the sire contribution to the weights. Under the assumption that the variances $\sigma_1^2 = \sigma_2^2 = \sigma^2$, we may state that $s^2 = 375.6$ is an unbiased estimate of the true variance σ_e^2 . Here we denote σ_e^2 as the expectation of the mean square:

	Expectation of Mean Squares
Between sires	$\sigma_e^2 + K \sigma_S^2$
Within sires	σ_e^2

The between-sire variance 1065.8 is composed of two components: that portion inherent in sample differences, as was noted from the original values, and that added portion due to the sire contribution. This variance is represented by $\sigma_e^2 + K \sigma_S^2$. Here we recall the between-sire variance is computed by $K \sum (\bar{y}_i - \bar{y})^2$ or the deviation for the individual sire squared weighted by the number of progeny per sire. So the component σ_S^2 , the added average contribution for the sire, must be multiplied by the number of progeny to provide estimates on an individual basis, as in σ_e^2 .

This deviation has been empirical rather than theoretical. The works by several authors lead to essentially the same results, depending on additional restrictions and definitions. For our purposes, it is sufficient to use these results for estimating the components.

While we are able to observe in this example the effect of adding the sire effect, in practice we can see only the results which include both the sire effect and the random variation of environment. Hence, we have the M.S. (sires) estimating $\sigma_e^2 + K \sigma_S^2$, and to obtain the sire contribution alone we need to remove the environmental effect. However, using our assumptions that the M.S. (within groups) is an unbiased estimate of σ_e^2 , we can estimate σ_S^2 as s_s^2

		M.S.	E.M.S.
from	Between sires	1065.8	$\sigma_e^2 + 10 \sigma_S^2$
	Within sires	375.6	σ_e^2
	$s_e^2 = 375.6$	$s_s^2 = \frac{1065.8 - 375.6}{10} = 69.0$	

These, then, are the estimates of the variance components for environmental and sire effects.

Now, consider a large animal population mating at random, the value of any attribute for an individual may be represented by

$$Y_{ij} = \mu + g_i + e_{ij}$$

where g_i is the genetic contribution and e_{ij} the environmental effect. This genetic value contains $1/2 g_i$ from each of the parents. The variance of the individual performances will then contain the genetic variance and environmental variance, or

$$V(Y) = V(g) + V(e)$$

assuming no interactions. The genetic variance will then consist of $1/4 \sigma_{g_1}^2$ from each of the parents plus the remaining $1/2 \sigma_{g_1}^2$ due to Mendelian segregation. In a beef cattle breeding program, where a number of offspring from the same individuals are not commonly available, estimates of genetic variances are based on half-sib sire relationships. Under such a situation, the observed performance contains $1/4 \sigma_g^2$ as genetic variance due to the sire effect, with the dam effect and segregation combined with the environmental effect. Then σ_e^2 will actually be $3/4 \sigma_g^2 + \sigma_e^2$, and σ_S^2 will be $1/4 \sigma_g^2$.

If we assume s sires and k offspring from each sire, each offspring having been produced by a mating of a sire to a random dam, the analysis of variance is

	d.f.	M.S.	E.M.S.
Among sires	$s - 1$	S	$(3/4 \sigma_g^2 + \sigma_e^2) + K (1/4 \sigma_g^2)$
Within sires	$s(k - 1)$	W	$(3/4 \sigma_g^2 + \sigma_e^2)$

where S is the among-sire mean square and W is the pooled within-sire variance.

As before, we can estimate

$$3/4 \sigma_g^2 + \sigma_e^2 = W \quad 1/4 \sigma_g^2 = 1/K (S - W)$$

then

$$\sigma_g^2 + \sigma_e^2 = W + 1/K (S - W)$$

and

$$\frac{\sigma_g^2}{\sigma_g^2 + \sigma_e^2} = \frac{4/K (S - W)}{W + 1/K (S - W)} = \frac{4 (S - W)}{S + (K - 1) W} = \frac{4 \sigma_S^2}{\sigma_S^2 + \sigma_e^2} = H$$

where H is the estimate denoted or heritability, as measured by the sire half-sib relationship.

Here, we must note, we have estimated heritability, the proportion of total variation which is due to genetic effect, from a factor which contained only one-fourth of the genetic variance. If, in fact, the estimate of σ_g^2 is poor in our sire component σ_S^2 , or is biased, then the error will be magnified by a factor of 4 in the estimate of σ_g^2 . This may often be the case if we have sire $\times$ herd or sire $\times$ year interactions present which have not been accounted for in the model.

Where the data are collected from several different herds (or years) and there are different sires used in each herd, the analysis is extended as follows:

	d.f.	M.S.	E.M.S.
Among herds	$t - 1$	T	$\sigma_e^2 + K \sigma_S^2 + KS \sigma_T^2$
Among sires in herds	$t(s - 1)$	S	$\sigma_e^2 + K \sigma_S^2$
Within sires	$ts(k - 1)$	W	σ_e^2

Where there are t herds, s sires per herd, and k progeny per sire, assuming all components are based on random samples from large populations. In situations where some of the elements in the model become "fixed" (i.e., the entire populations are represented in the samples), the arithmetic of the analysis is unaffected, but the components assume a different form, entailing additional complications in the estimation of the components.

Generally, the number of progeny per sire is not constant for all sires, so a simple modification in the analysis is made as follows:

	d.f.	M.S.	E.M.S.
Among sires	$s - 1$	S	$\sigma_e^2 + K_o \sigma_s^2$
Within sires	$\sum_i k_i - s$	W	σ_e^2

where $K_o = \frac{1}{s - 1} (\sum_i k_i - \frac{\sum_i k_i^2}{\sum_i k_i})$ is the "average" number of progeny per sire.

This estimate is generally smaller than the arithmetic mean of the number of progeny. In computing the among-sire sum of squares, the square of the deviation of group means from the over-all mean is multiplied by the number in each group separately, instead of using K_o . The estimation of the components and heritability estimates proceeds as before, with all such estimates being unbiased.

For the situation where data are obtained from several herds, we have:

	d.f.	M.S.	E.M.S.
Among herds	$t - 1$	T	$\sigma_e^2 + K_2 \sigma_s^2 + K_3 \sigma_T^2$
Sires within herds	$\sum_i s_i - t$	S	$\sigma_e^2 + K_1 \sigma_s^2$
Within sires	$\sum_i \sum_j k_{ij} - \sum_i s_i$	W	σ_e^2

The computation of mean squares for this hierarchical model is relatively simple and the mean squares are unbiased estimates of the expectations. The coefficient of σ_s^2 is different for the sire and herd estimates, with the computations of the coefficients of the component following a set of formulas similar to that given for K_o . The components are then estimated as

$$\begin{aligned} \sigma_e^2 &= W & \sigma_s^2 &= \frac{S - W}{K_1} & \sigma_T^2 &= \frac{T - K_2 \left(\frac{S - W}{K_1} \right) - W}{K_3} \end{aligned}$$

The problem becomes more difficult when the data are collected from several herds over several years, complicated by the varying number of sires and progeny. The basic model may include herd, year, and sire effects plus the interactions. There are many ways in which such a problem can be handled. In any situation it would be necessary to write out the specific model with all the assumptions and analyses of variance before any components can be

estimated. Obtaining the sums of squares for the various elements of the analysis of variance can be a considerable job in itself. As usual, the easiest ways from the point of view of labor often lead to biased estimates, particularly when some of the assumptions underlying the analysis are not fulfilled. The general least squares solution will provide unbiased estimates of the variances, but the computations are heavy and only with the use of a high-speed computer is there any relief, and even then the work still must be done by the individual. A paper by C. R. Henderson, Estimation of Variance and Covariance Components (Biom. 9:226-252, 1952) gives considerable detail on the methods of handling such nonorthogonal data. An article by D. C. Lowry (Biom. 11:136-148) discusses interpretation of these results.

The other aspect of variance component estimation which needs to be considered is the estimation of standard errors of these components to place confidence limits on the components and heritability estimates.

For the simplest case, the variance of a variance

$$V(\sigma^2) = \frac{2\sigma^4}{f}$$

where there are f degrees of freedom in estimating the variance.

Hence,

$$V(\sigma_e^2) = \frac{2\sigma_e^4}{s(k-1)}$$

for the situation with s sires and with k progeny per sire. For σ_S^2 , however, the problem is more complex, since the sire variance is a linear function of two variances. If we consider

$$\sigma_e^2 + k\sigma_S^2, \text{ then } V(\sigma_e^2 + k\sigma_S^2) = \frac{2(\sigma_e^2 + k\sigma_S^2)^2}{s-1}$$

then, since we estimated σ_S^2 from

$$\sigma_S^2 = \frac{(\sigma_e^2 + k\sigma_S^2) - \sigma_e^2}{k}$$

the variance of σ_S^2 will be related to the variance of a difference. The variance of a difference is

$$V(X - Y) = V(X) + V(Y) - 2 \text{Cov.}(XY)$$

Substituting in the previous values, we obtain

$$V(\sigma_S^2) = \frac{1}{k^2} \left[\frac{2(\sigma_e^2 + k\sigma_S^2)^2}{s-1} + \frac{2\sigma_e^4}{s(k-1)} \right]$$

where the covariance term is eliminated, since the variances of sires and environment are uncorrelated.

For the sample estimate, the d.f. are replaced by $f + 2$. The degrees of freedom for $V(\sigma_S^2)$ is still another problem, which will not be discussed, but in most cases may be considered as large enough to allow use of the normal deviate (1.96- for the 5 percent level) in placing confidence limits on the variance components. Where we have unequal numbers of progeny per sire, we may substitute k for k , but the variance of σ_S^2 is biased when k is used. If the number of progeny does not vary excessively from sire to sire, the loss of information is not too great.

Standard errors for heritability estimates are easily derived, but the form is usually messy for calculation. For the simple case used here, the results are easily obtained from the following:

$$H = \frac{4 \sigma_S^2}{\sigma_S^2 + \sigma_e^2}$$

If we let

$$\sigma_S^2 = X \quad \text{and} \quad \sigma_S^2 + \sigma_e^2 = Y$$

then

$$H = \frac{4X}{Y} \quad \text{and} \quad V(H) = 16 V\left(\frac{X}{Y}\right)$$

Now

$$V\left(\frac{X}{Y}\right) = \frac{1}{Y^2} [V(X) - \frac{2X}{Y} \text{Cov.}(XY) + \left(\frac{X}{Y}\right)^2 V(Y)]$$

which becomes

$$\frac{1}{Y^4} [W^2 V(\sigma_S^2) + (\sigma_S^2)^2 V(W)]$$

Substituting for $V(H)$, we have

$$\frac{16}{Y^4} \left\{ W^2 \left[\frac{2}{k} \left(\frac{S^2}{s-1} + \frac{W^2}{s(k-1)} \right) \right] + \frac{(S-W)^2}{k^2} \frac{2W^2}{s(k-1)} \right\}$$

where S is the sire mean square, W is the within-sire mean square, and H is the heritability coefficient. After suitable reduction, we obtain

$$V(H) = \frac{32 W^2}{(\sigma_S^2 + \sigma_e^2)^4 k^2} \left[\frac{S^2}{s-1} + \frac{(S-W)^2 + W^2}{s(k-1)} \right]$$

For the data in the example given

	d.f.	M.S.	E.M.S.
Between sires	1	1065.8	$\sigma_e^2 + 10 \sigma_s^2$
Within sires	18	375.6	σ_e^2

we obtain

$$s_e^2 = 375.6 \quad H = \frac{4 (69.0)}{69.0 + 375.6} = .622 \text{ or } 62.2\%$$

$$s_s^2 = 69.0$$

and

$$V(H) = \frac{32 (375.6)^2}{(444.6)^4 (10)^2} \left[\frac{(1065.8)^2}{3} + \frac{(1065.8 - 375.6)^2}{20} + (375.6)^2 \right] = .473$$

using $(s - 1) + 2 = 3$, and $s(k - 1) + 2 = 20$, for degrees of freedom for estimating sample variances.

Then the 95 percent confidence interval for H would be $.62 \pm 1.96 (.47)$ which is much too wide to be of practical value.

From the above formulas we may observe that estimates of variances of variance are extremely poor when the number of degrees of freedom are small. Hence, estimates of heritability estimates based on small degrees of freedom will be of little value because of the wide confidence intervals. This places doubt on the reliability of heritability estimates and other measures of sire ability to transmit characteristics which are based on a small number of progeny. Breeding programs cannot be evaluated effectively with only a small number of sire or progeny records. When data are collected over a period of time, considerable improvement in the reliability of estimates can be made, but the formulations of appropriate models and computational procedures become an additional complication.

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REPRODUCTIVE PHYSIOLOGY IN THE COW AS RELATED TO GENETIC IMPROVEMENT

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Two major factors which limit genetic improvement of beef cattle are: (1) the relatively low reproduction rate per year and, (2) the long interval between generations. Both of these reduce the rate of progress from mass selection, the first by allowing for a smaller selection differential and the second by reducing the average annual increase in performance.

It is commonly conceded that multiple births in cattle are undesirable because of the occurrence of the "freemartin" condition in the female of twins of unlike sex. This condition apparently arises from an anastomosis of the fetal circulations (Lillie, 1917). This allows the embryonic sex hormones of the male twin to pass into the circulation of the female twin and prevent the development of the gonadal cortex and differentiation and development of certain portions of the Mullerian duct system.

Twinning in cattle appears to be at least partially genetically controlled as evidenced by the differences in incidence between beef and dairy cattle, different breeds and families within breeds. However, age of dam appears to be a major factor in determining the frequency of twin offspring. Also, Asdell (1953) has suggested that chronic infection with vibriosis may also be a factor in increasing the proportion of twin births.

The major problem in cattle reproduction is not the production of multiple offspring. It is the failure of some cows to produce even one offspring per year. According to Ensminger et al. (1955) approximately 20 percent of cows and heifers in the breeding herds which they studied failed to produce live calves in 1954. Undoubtedly there are many causes for this infertility, such as failure to exhibit estrus, failure to ovulate, failure of fertilization, physical abnormalities of the reproduction tract, and embryonic death.

Lagerlöf and Boyd (1953) and Lagerlöf and Settergren (1953) reported a condition known as ovarian hypoplasia which occurs in Swedish Highland cattle. In those animals with bilateral ovarian hypoplasia the heifer has the appearance of a castrate, secondary sex characters fail to develop, the reproductive organs remain infantile, and the animal fails to come in heat. If the condition is unilateral, the animal usually has normal reproductive organs and exhibits normal estrual cycles. This condition was rather widespread in the Swedish Highland breed and in 1935 affected 30 percent of the animals. Rigid control measures had reduced the incidence to about 9 percent in 1948. According to Lagerlöf (1951), this anomaly is caused by an autosomal recessive gene with reduced penetrance.

Another condition which may cause "lack of heat" in the cow is a persistent corpus luteum in which the corpus luteum is functional beyond its normal life. It is not known to what extent this may be genetic. The common treatment is to enucleate the corpus luteum, which will usually produce estrus in three to four days. Since the corpus luteum persists throughout pregnancy in the cow, what may be diagnosed as a persistent corpus luteum may be a normal pregnancy. Expression of the corpus luteum in this case will cause abortion or resorption. One should be very certain, therefore, that the cow is actually not pregnant before attempting any treatment.

Also, a lack of heat in yearling heifers that are being bred to calve at two years of age may occur because the animals have not reached puberty. Although recent data from the University of Idaho (Christian, 1957, and unpublished) indicate that the average age of puberty in the beef heifer is approximately 375 days, some do not come into heat until about 14 or 15 months of age. This may account, in part, for the lower conception rate in heifers bred to calve at two years of age.

The average interval from parturition to first estrus in the beef cow has been reported to be 80.2 days by Lasley and Bogart (1943) and 62.7 days in Hereford cows by Warnick (1955). This may result in failure to show heat, at least in the early portion of the breeding season.

Failure of ovulation may occur in beef cattle, although there is no reliable estimate of how frequent this condition occurs. In some cases the follicle may undergo atresia and a normal estrus may occur at a later date. In other cases the follicle may become luteinized without rupturing. These animals may also return to normal estrus later. In other animals the follicle(s) may continue to grow without rupturing and form follicular cysts. Cystic ovaries occur more frequently in dairy cattle than in beef cattle. Casida and Chapman (1951) found that 18.8 percent of Holstein cows studied were affected during a 10-year period. They also estimated the heritability of the occurrence of cystic ovaries to be 0.43. The physiological cause of cystic ovaries is not fully understood. It may be due either to a deficiency of the luteinizing hormone from the anterior pituitary or the follicles formed may not respond (ovulate) to the normal hormone stimulus.

The spontaneous recovery rate from cystic ovaries is quite high. However, the condition may occur more than once.

Failure of fertilization is an important cause of infertility in cattle, although the frequency has not been estimated in beef cattle. In dairy cattle the percentage of ova fertilized when first service heifers are inseminated with semen from bulls of high fertility (67-79 percent 60-90 day nonreturn) approached 100 percent, but when inseminated with semen from bulls of low fertility (40-66 percent 60-90 day nonreturn) the rate of fertilization was 71.9 percent (Kidder et al., 1954). In all, 12.2 percent of the ova were not fertilized, with no apparent cause. This percentage is perhaps lower

than would be encountered in natural service since the bulls used were a selected group (no completely infertile bulls were used). There are probably many reasons for fertilization failure in the cow. It could be due to production of faulty ova by the cow or faulty sperm by the bull or both, failure of sperm transport, abnormal physiological condition in the female reproductive tract which renders the sperm infertile, or over-aging of either the egg or sperm or both. Many of these causes of fertilization failure have been demonstrated experimentally.

In the study cited above, Kidder, et al., found 9.5 percent defective ova in first-service heifers. It is not unusual to find many sperm with gross morphological abnormalities in nearly every semen sample. In some cases nearly all sperm are deformed. Undoubtedly there are other abnormalities of both ova and sperm which render them incapable of fertilization that do not show up in gross microscopic examination.

Sperm transport is very rapid in the cow. Sperm have been found in the oviduct within a few minutes following insemination (Van Demark, 1954). For this reason the primary cause of failure of sperm transport is probably physical barriers in the reproductive tract of the female such as hydrosalpinx, salpingitis, and bursitis (Tanabe and Casida, 1949).

It is not known to what extent there are abnormal physiological conditions in the female reproductive tract which render the sperm infertile. Theoretically, abnormal pH in the reproductive tract or the presence of infections might act in this way. This point has not been tested experimentally, although there are many clinical studies which point in this direction.

As reviewed by Chang and Pincus (1951), bull sperm probably retain their ability to fertilize ova for 24 to 30 hours after being deposited in the female reproductive tract, and cow ova have a life span of 8 to 10 hours after ovulation. Since the length of estrus in the cow is usually 16 to 20 hours, and the usual time of ovulation is 10 to 14 hours after the end of heat (Rice et al., 1957), over-aging of the sperm probably is not a factor in natural mating unless the female is bred only once very early in estrus. Also, over-aging of the ovum does not occur with natural mating since ovulation in the cow does not occur until after the end of the estrus. Both of these factors may be important where artificial insemination is practiced, as was reported by Trimberger and Davis (1943).

Physical abnormalities of the female reproductive tract are known to be important causes of infertility in cattle. An inherited condition known as "white heifer disease" has been described which affects primarily white Shorthorns, although roan and red Shorthorns as well as colored animals of other breeds may be affected.

Spriggs (1946) recognizes three distinct types of white heifer disease. Group A is characterized by the absence of the anterior vagina, cervix, and

uterine body, and also has a cystic distension of the uterine horns. This type is always sterile. Group B is characterized as having a uterus unicornis. The abnormal horn is present as a flat muscular band with a cystic formation near the apex. Reproduction is possible in this group. Group C is characterized as having a hymenal constriction with the rest of the reproductive tract being normal. White heifer disease is the result of arrested development of the Mullerian ducts due to the mesodermal somites being affected. The development of the uterus and anterior vagina is incomplete; however, the vulva and ovaries are normal.

Other physical abnormalities which produce infertility are hydrosalpinx, salpingitis, and bursitis. Tanabe and Casida (1949) found genital abnormalities in 10.6 percent of the repeat breeder cows they studied, even though an attempt was made to exclude cows with these conditions. Also, Burns et al., (1954) reported that 5 percent of the cows of Brahman breeding which they studied had unilateral pyosalpinx. Most of these tubal abnormalities probably are permanent and would not respond to treatment. Therefore their diagnosis is very important so that the affected animals can be removed from the herd.

The importance of embryonic death as a cause of infertility in cattle has become increasingly apparent in the last decade, although Hammond in England reported as early as 1914 that in the sow only about 70 percent of the corpora lutea were represented by normal fetuses. The studies by Tanabe and Casida (1949), Laing (1949), Christian et al., (1949, 1951), Kidder et al., (1954) have reported an embryonic death rate in cattle during the first 60 to 90 days of gestation of 30 to 40 percent. These reports indicate that early embryonic mortality is fully as important as fertilization failure in causing "repeat-breeding" in cattle.

The causes of early embryonic death are not clear. Lethal genes probably are responsible for at least a portion of the early deaths. However, in the author's opinion, relatively little of the embryonic death in cattle is due to lethal genes which cause early death of the embryo, except in isolated cases. Most of the studies on the causes of embryonic death in the cow have been tests of empirical treatments, such as increasing the ascorbic acid level (Christian, et al., 1951), crossbreeding (Christian et al., 1951), and uterine douche with antibiotics (Ulberg et al., 1952). None of these treatments appears to be effective in improving fertility in low-fertility cows. Other attempts have been made to find factors that may be associated with embryonic death. Most of these attempts have failed to yield positive results. However, Christian and Casida (1951) reported that the bull used at first service may affect the fertility of his return cows. The effect is more pronounced in the return cows from bulls of low fertility than from bulls of average or high fertility.

Another factor which may be associated with embryonic death is that the defensive mechanism of the uterus to the presence of foreign materials of the

repeat breeder cow appears to be more sensitive than in the first-service cow (Casida, 1953).

Many attempts have been made to estimate the heritability of breeding efficiency in cattle, using various criteria such as services per conception, average length of the interval between calvings, length of the post-partum interval, nonreturn rate to first service, etc.

Most of the studies have reported the heritability of breeding efficiency to be very low (see review by Rollinson, 1955). All of these methods of estimating the heritability of fertility generally include only fertile animals. Those animals which never reproduce or are culled before reproducing are not included. Thus, these estimates may be biased. The indications are, however, that selection for fertility in cattle would not be very effective. Selection for fertility in beef cattle should not be so intense as to materially lower the amount of selection practiced for other economically important traits.

These results might be expected when it is realized that fertility is the result of the proper functioning of many separate phenomena, and as suggested by Casida (1956) most of the genetic variation may be nonadditive. It would appear then that, under present conditions, more improvement can be made in reproductive efficiency by improvement of the environment than by selection.

Perhaps, when the amount of environmental variation is reduced, we will find that fertility is heritable.

This immediately poses the problem of what to do with animals that fail to reproduce in any given year; should they be culled or should they be given another chance? If they are diagnosed as having a condition which is of a permanent nature, they should be culled. Otherwise, the decision will depend upon the cost of maintaining an open animal for an additional year and on the availability of replacements.

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GENETIC-ENVIRONMENTAL INTERACTIONS

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According to Lerner (1950) one of the fundamental postulates of applied population genetics may be stated, "The phenotypic variance of a Character is determined by genetic and environmental forces. It can be entirely accounted for by these two factors and by the interactions between them." The implied relation may be written:

$$\sigma_P^2 = \sigma_{Ge}^2 + \sigma_E^2 + 2r_{GeE} \sigma_{Ge} \sigma_E + f (GeE)$$

It should be noted that the genetic variance σ_{Ge}^2 may be partitioned into additive, σ_G^2 , and nonadditive, σ_G^2 , effects and that the environmental variance, σ_E^2 , may be divided into that part which varies at random between and within families, σ_E^2 , and that part due to influences common to members of the same family but varying from family to family, σ_C^2 . The penultimate term refers to correlations between genotypes and environment and the final term to nonlinear genotype-environment interaction, which is the subject of this brief review.

Lerner (1950) probably reflected the thinking of most investigators at that time when he wrote, "For most practical purposes . . . genotype-environment interaction may be neglected." However, the possibility that these interactions might be of importance was clearly recognized, for he also wrote, "The usual aim of the breeder is to obtain a population which is characterized by an average genotype superior to all other genotypes under all possible environments. Obviously, such an aim may not be possible of realization if nonlinear interactions between genotypes and environments exist. Haldane (1946) recently presented a formulation of this problem which we can adopt in abbreviated form for our purposes. Let us consider, for the sake of simplicity, only two genotypes, A and B, and two different environments, X and Y. If we adopt the convention that genotype A in environment X (AX) is superior to the other combinations in performance with respect to a given trait, there are six possible ways in which rankings of the two genotypes in each of the two environments can occur (table 1).

Table 1.--The possible types of genotype-environment interaction between genotypes A and B and environments X and Y (From Lerner, after Haldane, 1946)

Type of Interaction	Rank				Best Genotype for Given Environment	
	1	2	3	4	X	Y
1	AX	AY	BX	BY	A	A
2	AX	BX	AY	BY	A	A
3	AX	AY	BY	BX	A	A
4	AX	BX	BY	AY	A	B
5	AX	BY	AY	BX	A	B
6	AX	BY	BX	AY	A	B

"In the first three types the interaction is linear, and genotype A is superior to B under both environments. Hence, here the breeder's goal would be to replace B entirely by A, no matter which environment was to be provided for the animals. The last three types of interaction are non-linear. Here the two genotypes have different optimum environments, so that genotype A is found superior to B under environment X, while the opposite is true under environment Y. The aim of the breeder . . . would be to provide the right genotype for each of the given environments. The husbandman . . . will attempt to provide the right environment for a given genotype."

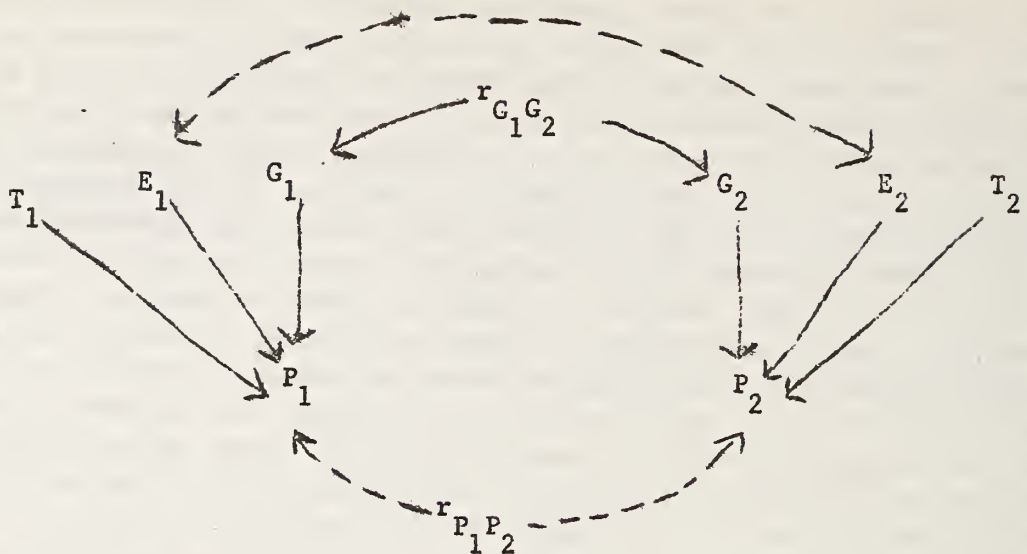
In practice the general problem may be, in fact most likely is, much more complex than this deceptively simple formulation indicates. There may be an infinite number of genotypes and an equal number of environments. Further, genotypes may change from generation to generation and no environment is truly stable or constant. Despite these obvious difficulties, it is feasible to speak of an "average aggregate genotype" for a particular metric trait and to consider reasonably logical distinctions among levels of environmental variation. In the case of beef cattle, examples of the latter might include such things as temperatures, humidity, altitude, nutrition, photoperiods, management system, etc., and all combinations among them.

A simple, familiar example of a genetic-environment interaction might prove instructive. In England and in some localities on the continent of Europe, dark variants, due to single dominant mutant genes, appeared in several species of moths about one hundred years ago. These variants have become the predominant form in populations in these localities where the surroundings are polluted and darkened by industrial air exhausts, the white form remaining predominant in unpolluted areas. If we consider adaptability as a trait, there are three genotypes (two giving rise to the same phenotype) and two environments. Clearly, the two genotypes resulting in the dark form are superior in the industrial environment, and the one giving rise to the light form is superior in the agricultural environment.

The existence of nonlinear genetic-environmental interactions would be of great significance to practical, applied beef cattle improvement in many parts of the West. In these areas commercial beef production is almost entirely a range operation with quite rigorous environmental conditions (climatic, nutritional) frequently prevailing. Range operators depend to a large extent on the genetic force of migration, by the purchase of "improved" range bulls for practical improvement. The purchased bulls are almost always produced in herds maintained under farm conditions and are themselves well fed. Many are produced in a more salubrious climate. Consequently, genetic improvement of many range herds is largely contingent upon improvement of bulls produced under environmental conditions much different from those in which they and their progeny are expected to perform. This situation gives rise to several questions. Does an environment favorable to the expression of a trait allow most rapid progress under selection, or does an unfavorable environment, by exerting greater physiological stress, permit most rapid progress for expression in either environment? Does the expression of a trait in one environment (rigorous) have a different genetic basis from its expression in another more favorable one? In other words, are genotype-environment interactions important?

Hammond (1947) expressed the view that an environment most favorable to the expression of a desired trait would allow most rapid progress under selection; and that if the improved population is then transferred to less favorable conditions it will have attained a higher level of performance than could have been attained by the same amount of selection under less favorable conditions. Falconer (1952) agreed that one might expect performance in a favorable environment to have a different genetic basis from performance in an unfavorable one, i.e., genetic-environment interactions might be expected. If this were true, it would follow that selection should be practiced in the environment in which the improved population is destined to perform.

The remainder of this review will consider briefly the several methods of estimating genetic-environmental correlations, and the results of a few pertinent applications. Falconer (1952) pointed out that, if only two environments are considered, the interaction may be expressed as a genetic correlation. Assume a trait is measured in two different environments so that distinct differences in phenotypic expression result. The two measurements are not regarded as representing a single trait, but two different ones; and the two environments considered as "treatments" which have to be applied so the characters may be measured.



The situation is illustrated by the path diagram. P_1 and P_2 represent the phenotypes as measured in the two environments. Three sources of variation affect each phenotype: the two genotypes, G_1 and G_2 ; environmental differences not associated with treatments, E_1 and E_2 . The two phenotypes are correlated through a genetic and, at least potentially, an environmental path. The genotypes are connected by a genetic correlation,

$$r_{G_1 G_2}$$

and the square roots of the two heritabilities. Estimates of the parameters,

$$r_{G_1 G_2}, h_1, \text{ and } h_2$$

are all that are required for solution of the problem.

The two phenotypes are not measurable in the same individual; hence, the environmental and phenotypic correlations have no reality but may be regarded as being potentially existent in every individual. The genetic correlation is present in every individual since all individuals possess genes corresponding to both genotypes, even though only one genotype can find expression in a phenotype in any one individual. It is assumed that environmental variations are not correlated with genotype, and that environmental variation within treatment is small in relation to differences between treatments.

The technique is to divide a population into two strains, and select for P_1 in environment E_1 in one strain, and for P_2 in E_2 in the other, the basis and intensity of selection being equal in the two strains. After some generations of selection (sufficient to elicit response), some individuals of each strain are subjected to the treatment appropriate to the other, so that both phenotypes are measured in both strains. Assume we

are interested in the phenotype P_1 , which is the trait in the unfavorable environment E_1 . The problem is to estimate the amount of improvement in P_1 obtained as a correlated response to selection for P_2 , and to compare this with the improvement in P_1 obtained by direct selection. The magnitude of the direct response is

$$\Delta G_1 = t h_1 \sigma_{G_1}$$

(Hazel, 1943); and the correlated response is

$$\Delta' G_1 = t h_2 r_{G_1 G_2} \sigma_{G_1}$$

Since the selection differential, t , is the same for both strains, the ratio of the correlated to the direct response becomes

$$\frac{\text{correlated response}}{\text{direct response}} = \frac{\Delta' G_1}{\Delta G_1} = \frac{h_2 r_{G_1 G_2}}{h_1}$$

The correlated response may be evaluated in terms of the two heritabilities and the genetic correlation. The genetic correlation may be estimated by the method developed by Hazel (1943). An advantage of selection in the more favorable environment would accrue only if the product

$$h_2 r_{G_1 G_2}$$

were greater than h_1 . Since all three parameters may vary widely depending upon the particular circumstance, a general conclusion about the relative merits of the two methods of selection is impossible. It would appear that the expectation of a much higher heritability in the more favorable environment, not offset by a decrease in genetic correlation, would be the major justification for practicing selection in the more favorable environment.

Falconer and Latyszewski (1952) described an experiment in which two strains of mice were selected for body weight, one on a high plane of nutrition and the other on a low plane. After 5, 7, and 8 generations of selection, performance of each strain on the diet appropriate to the other was measured. Neither of the two correlated responses was as great as the direct response; but when compared with the corresponding direct response, the correlated response following selection on the low plane was much greater than the correlated response following selection on the high plane. The heritability was higher on the lower plane.

Neither the heritabilities nor the correlated responses were very exactly determined, but they serve to illustrate the method. The observed heritabilities were 0.2 and 0.3 on the high and low planes, and the ratio of the correlated to the direct response for weight on the high plane was about 0.8. Therefore, substituting in the appropriate equation

$$r_{G_1 G_2} \frac{\sqrt{0.3}}{\sqrt{0.2}} = 0.8 ; r_{G_1 G_2} = 0.65$$

the other correlated response was estimated to be zero, which is impossible. Taking the value found for

$$r_{G_1 G_2}$$

the expected ratio of correlated to direct response is about 0.5. The observations were thought to be consistent with this value.

Morley (1955) investigated the interactions between genotype and plane of nutrition in Australian Merino sheep. Genetic variability was increased by using small flocks in which selection had been practiced for and against clean fleece weight and crimps per inch. An additional group of offspring of progeny tested sires and selected ewes was used. Each of the twenty-four sire groups (half-sibs) was divided equally, one group being kept on a high plane of nutrition and the other on a low plane. The traits measured were: greasy fleece weight, yield, clean fleece weight, staple length, crimps per inch, and body weight at 6, 12, and 17 months of age.

All data were transformed to logarithms to equalize variances within treatments. Intraclass correlation among half-sibs was estimated by the usual method within each treatment. The combined analysis of the two treatments, and estimation of variance components followed the usual lines. Significant differences between treatments were observed for all traits except yield and crimps per inch. Intraclass correlations did not differ between treatments.

The sire $\times$ treatment interactions were considered as measures of genotype-environment interaction. Such interactions were observed for body weights at 12 and 17 months, but not for any of the other traits. The results indicate that, in this situation, fleece production on one plane of nutrition provides a good indication of that on the other. But this is not true for body weight at latter stages of growth.

The genetic correlation between the characteristics determining body weight on high and low planes, which may be written $S/(S+I)$, if S is the sire and I the interaction component, is approximately 0.16 at 12 months and 0.29 at 17 months. That is, selection for high body weight on one plane of nutrition may be only 15 to 30 percent effective under another.

Morley (1955) feels the experimental method employed in this investigation is superior to that of Falconer and Latyszewski (1952). He suggests their method is impractical for livestock because of the number of generations and the need for avoiding temporal variation in environment. Morley did not indicate the number of generations involved in his material. He pointed out that, for most traits, the variance among sires was three to four times as large as would be expected in a random bred flock.

A third method of estimating genetic-environmental interactions has been described by Allard (1956). The method results from an extension of the analysis of diallel crosses. The necessary assumptions (homozygous lines) would appear to restrict the utility of the method to plant material. It is not, therefore, reviewed in detail here.

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UNFAVORABLE ENVIRONMENTS AND CATTLE BREEDING PROBLEMS

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In nature, cattle become eminently suited to their environment by the process of selection, i.e., elimination by death of those unsuited to their environmental conditions. This natural selection, however, is slow and wasteful, entailing the death of many animals. In the artificial selection and improvement of cattle for unfavorable environments, scientific methods are required to speed this process and to do it with the least possible waste.

Breeds of cattle differ widely in their ability to thrive and to perform efficiently under given conditions. Some breeds are adapted to temperate climates, while others are more suited to the tropics. Certain types, such as the yak, thrive at high altitudes; others cannot survive satisfactorily there. Breeds vary also in their grazing preferences. Some can obtain a satisfactory living while grazing over extensive range lands. Others require lush pastures and supplemental feeding if they are to perform efficiently. On the eastern seaboard of New Zealand, where the wind blows continuously, a herd of Angus cattle which has been bred for a period of 40 years in the area carries hair as long as that of Galloway cattle to withstand the wind. The Highland cattle in Scotland must also endure moist cold winds and as a result grow very long hair.

The environment comprises the aggregate of all external conditions and influences affecting the animal. These conditions are the climate, topography, agro-ecological conditions, animal management, plane of nutrition, disease, agricultural policies, and culture. The climate is a complex made up of a number of variables; namely, temperature, sunlight, infra-red components, cloud cover, relative humidity, rainfall, and even cosmic rays. These components affect soil physics and chemistry, yields and composition of crops and pastures, and virtually every function of the animal. Climatically, the world is divided into zones--frigid, temperate, and torrid.

The significant role of the environment has been realized in different countries. The European Association of Animal Production at present is devoting the annual Meetings (Madrid, 1956, Rome, 1957) to discussing the influence of climate on animal production. The "Institute of Animal Breeding and Veterinary Medicine for Hot Climates" in France is concerned with cattle productivity in relation to the irrigation and conservation of pastures, disease, and parasites (I.E.V.M., 1958).

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The Favorable Environment

The healthy, high-producing animal is in delicate balance with its environment. Such animals are adjusted not only to the average conditions, but also to the extreme environmental fluctuations. The superiority of cattle population in favored areas in the world is mainly due to compatability. Compatability is a complex phenomenon that cannot be reduced to a single type of measurement without grossly oversimplifying the concept. Numbers are important in a consideration of compatability, but must be placed in their proper perspective in relation to economic needs.

The best illustration for the adjustment is that of anatomical compatability in body conformation, size, shape, and body coat. Types and breeds of cattle found in, and adapted to, semiarid subtropical regions are not small-framed cattle, these being found instead in the humid subtropics and also in areas where soils are acid. Heat dissipation in the humid tropics is more difficult than in the drier tropics; hence a large skin area per unit weight is desirable, this being characteristic of certain breeds and strains of the "respiratory" type. Breeds of cattle developed in torrid regions have thick hides with greater vascularity of hide, an attribute which promotes the dissipation of heat. Such breeds have hides with many vertical skin folds and a well-developed panniculus muscle. Secretions from the hide, the growth of the coat, the amount and distribution of adipose tissue under the hide, and the healing of wounds are regulated by both the endocrine and nervous systems and are indicative of an animal's compatability to a particular environment. Anatomical compatability with respect to hair coat (Hafez, et al., 1955a) and to the physiological reaction (Hafez, 1956) has been studied. From the commercial point of view, the main advantages of compatability are: 1. Livability, hardiness, and resistance to disease (often called "constitution") for it is more profitable to have a comparatively less improved animal which will live longer than a much improved one which may have only a short life; 2. A high rate of reproduction so that populations can be expanded quickly to meet needs and reduce the overhead charges on the maintenance of breeding stock; and, 3. A good growth rate, suitable body proportions for meat production associated with the efficient conversion of feeds.

The Unfavorable Environment

Unfavorable environment directly reduces the productivity and fertility level and increases the mortality rate. Indirectly, poor environment reduces the quality of animal products through such things as susceptibility to disease, parasites, stress, and bruises. Breeds of cattle differ in their degrees of merits under a given favorable environment. If they are moved to an unfavorable environment they will rank differently. If transferred to another unfavorable environment these breeds may rank in a still different way. Some of the breeds may revert to "scrubs" or even die (Figure 1). Each unfavorable environment exerts certain types of stress on the animal. There are three major effects of stress.

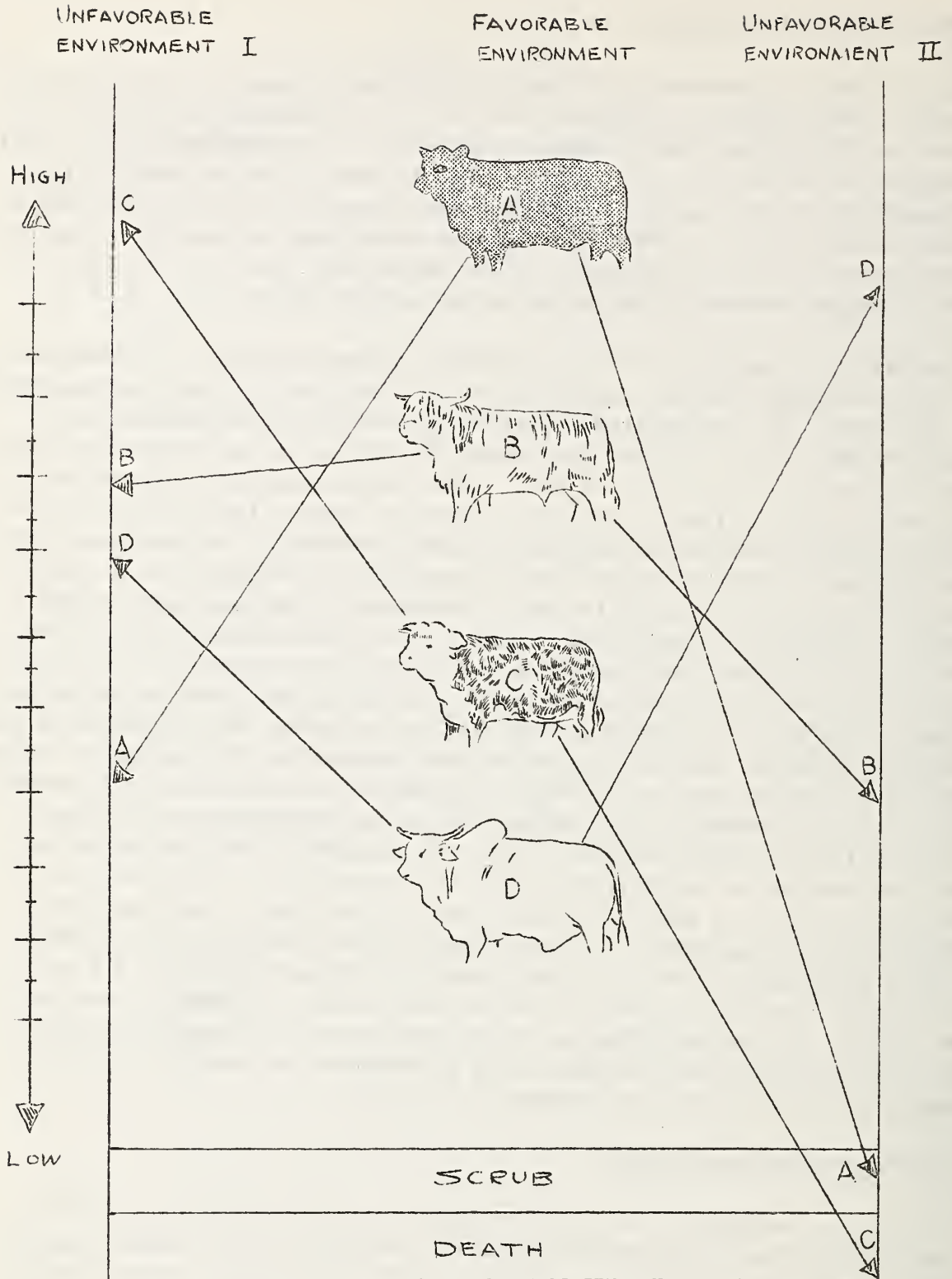


Figure 1.--Diagrammatic illustration of the effect of unfavorable environments on productivity of cattle. Breeds A, B, C, and D are ranked according to their productive capacity in a given favorable environment (middle scale). If these breeds are moved to an unfavorable environment I (left scale) they will rank differently according to their individual reactions to the prevailing stressors. If transferred to another unfavorable environment II (right scale) they still rank differently; some of the breeds may revert to scrubs or die.

1. Alarm phase: This is the stage immediately after the stress is imposed on the animal. The speed and manner in which this stage occurs vary with the type of stress, breed, and age.
2. Resistance phase: This stage begins promptly and continues until the optimum adaptation to that stress has been achieved by the animal; every part of the animal's body is involved. If the alarm stimulus is discontinued, the body accepts the stimulus as a part of the usual environment.
3. Exhaustion phase: The animal reaches this stage if it is unable to build up resistance to the stress or if the resistance has been lost. Death of the animal usually follows

We should not completely eliminate stress, for only by subjecting the animals to stressors can the animal build up immunity. The discussion to follow will deal with the effects of climatic, genetic, nutritional, management, and disease stress on animal breeding problems. This will be followed by recommendations for cattle breeding under unfavorable environments and suggestions on future research.

I. Climatic Stress

This includes radiation, thermal, cold, and drought stress.

A. Radiation Stress

The amount of solar radiation received varies with geography and climate. Field measurement of solar radiation is still a problem. The reaction of cattle to radiation stress could be measured by the rate of decrease in respiration and pulse rate in shade after exposure to solar radiation for a comparable length of time (Hafez, 1954).

Biological Principles

The reflection of rays depends on hair direction, grouping, intensity, and structure (length, thickness, medullation and fat content of sebum), and skin color. The shedding of hair is affected by daylight environment. Prominent eye brows and their bony ridges provide natural protection from sunlight. Light waves also cause chemical reactions and of these waves the ultra-violet beam has the strongest oxidizing action.

The coat color (hair and hide) is genetically conditioned and results from quantitative and qualitative modifications of melanin. Melanin distribution varies with the breed and skin region. Melanin biosynthesis is controlled by gene-induced enzymes. Radiation may activate tyrosinase; this helps in the formation of 3, 4-dihydroxyphenylalanine. Skin pigmentation is under the control of melanin-stimulating hormone, recently isolated from the anterior pituitary (Lerner and Takahashi, 1956).

The reflection and absorption capacity of skin varies with the breed, degree of pigmentation, and season (light intensity and air temperature). Intense radiation is associated with large skin surface and sensitivity of pilomuscles. Skin conductivity depends on its thickness, keratinization, pigmentation, nature of skin strata, elastic properties, and subcutaneous fat.

Radiation Threshold

Radiation increases the rate of metabolic processes; beyond a certain threshold level of exposure, pathological conditions occur such as injuries, epithelioma, facial eczema, pink eye, and sunburned udder. Skin cancers and dermatitis are usually found in cattle with white hair and a white skin. If such cattle eat certain plants, the hide becomes supersensitive to radiation stress. Hereford cattle, with their white faces and unpigmented eyelids, are susceptible to eye cancers and epithelioma if subjected to severe solar radiation. The cancers develop exclusively on the conjunctiva in individuals where the conjunctiva is deficient in pigment (Guilbert et al., 1948). Cancers also develop on those parts of the eyelids which are not covered with hair and which are unpigmented.

B. Thermal Stress

The metabolic heat in the body must be dissipated as soon as it is produced, else the body temperature rises above the normal. A rise in body temperature of only 8° F. above normal is often quickly fatal, and the efficiency of the body machine deteriorates rapidly even with slight increases in body temperature. Temperate breeds have less developed dewlaps and much less developed umbilical folds. The scrotums of the bulls are long and pendulous and are prone to injury, causing impairment to the thermoregulatory function of the scrotum and resulting in sterility.

A split-twin project was undertaken jointly, by the Department of Agriculture of New Zealand and of Fiji, to assess the influence of thermal stress per se upon growth in cattle (Hancock and Payne, 1955). Eight pairs of monozygotic twins were divided at 6 months of age. One group was reared in New Zealand (latitude 40° S); their mates were sent to Fiji (latitude 17° S). Differences in growth rate were of a much smaller magnitude than differences in other productive qualities such as lactation.

The normal diurnal variations of rectal temperature have been studied in calves (Beakley and Findlay, 1955a). The extent of these fluctuations seems to be a valuable indication of the ability of cattle to withstand thermal stress. There are striking differences in the reaction of calves of the same breed identically fed and managed. This result suggests the large degree of heat tolerance existing not only between breeds, but also within them. However, the extent of the rise in rectal temperature may not always be reliable as a measure of the probable productivity of temperate breeds in the tropics (Payne and Hancock, 1957). The variable

nature of pulse rate and the fact that so many factors affect it make the pulse an unreliable index of heat tolerance in young bovines (Beakley and Findlay, 1955b). The environmental temperature is significantly correlated with blood cholesterol and thyroid function. Brahman cattle react more to lower temperatures than do crosses and show a greater seasonal variation in blood cholesterol (Anderson, 1956).

Five years of research have shown that spraying the animals, cooling evaporation air, cooling air surface by evaporation, and cooling the drinking water have some benefit in increasing weight gains of animals under thermal stress (Kelley et al., 1955). Increasing the air movement in a wooden corral to 325 c.f.m. with a fan increases the rate of gain 0.5 to 1.0 lb. per day (Ittner, et al., 1957). Studies of heat gain in relation to surface of buildings and livestock under summertime conditions indicate that the sol-air temperature concept has value as an index for comparing different surfaces as to their effectiveness in reducing heat gain under thermal stress (Nelson et al., 1954).

Effects of Age

The extent of thermal stress is very pronounced in the calf because its power of heat regulation is not well developed at birth. This explains the high mortality rate in calves of temperate breeds under thermal stress. The heat regulatory mechanisms gradually develop as the animal grows up. When the cow is poorly nourished during the later stages of pregnancy, the development of the heat regulating powers of the calf is retarded so that it suffers more from extreme of heat and cold than do those which are well developed at birth. For this reason the differences in heat regulation between breeds are much more marked in calves than in adult cows. A small as contrasted to a large rise in body temperature in the calf under thermal stress may form a basis for selecting those which will be profitable cows under these conditions. For this reason too, moderately mature cattle will suffer less than will young calves when imported from temperate to torrid climates.

Effects of Altitude

When assessing the thermal stress we have to consider the monthly and diurnal variations in temperature in relation to altitude. Such relationship has been illustrated for three close localities in Arizona (Table 1). The diurnal variation is large during the warmest months and the dry air helps to make the intense heat tolerable, especially if followed by cool nights. The lowlands of Arizona and the Colorado desert have temperatures comparable with those of the Sahara. The highest record for North America (Kendrew, 1955) is 134° F., July 10, 1913, in Death Valley, California, altitude -276 feet, where the July mean is 102°.

Table 1.--Altitude-temperature relationship in three localities in Arizona

Locality	Altitude Above Sea-level (ft. approx.)	Atmospheric Temperature F. ^o	
		Mean (July)	Absolute (Max.)
Mohawk Summit (Gila R.)	540	95	126
Tucson	2,400	85	111
Patagonia	4,900	79	111

High-altitude cattle such as the Brown Swiss have by far the highest blood count of all breeds. In South Africa, the Afrikaner breed has the highest blood count of the breeds there. The tropical adaptability of the Brown Swiss breed centers around this point, since both at high altitudes and at high temperatures the animal must contend with rarified air.

At high altitudes ultra-violet impingement is tremendous as it is in the tropical regions. At the same time infra-red radiation is intense and a dark-colored rather than a light-colored animal is preferable, especially at the higher altitudes where infra-red radiation is required as a source of energy. In the tropics, however, infra-red radiation is not required as a source of energy and is therefore a problem.

Because of these common ultra-violet and infra-red radiation problems, there are many similarities between the animal adapted to the low altitude subtropics and the animal adapted to very high altitudes.

In high altitude areas the animals lose weight rapidly the moment they are exposed to severe cold winds during the winter. If these animals are to overcome the cold, they must be provided with more heat or extra feed. If this is not available, they rapidly lose condition. To reduce feed intake at these cold, high altitudes, shelter must be provided.

The altitude exerts a significant effect on longevity, growth rate, and lactation. At high altitudes, the Brown Swiss young bulls are smaller and lighter than in the lowlands while in the adult cows the weight is affected but not the body measurements (Engeler, 1957).

Another aspect worthy of consideration is that at high altitudes the soils are more acid, and it is certain that there under natural conditions one will never raise large animals. They will always be smaller than those bred on the plains in regions where there are usually lime deposits in the soil.

Coat Shedding

One of the major factors in increasing the thermal stress is coat retention in the summer. Recent research work in Australia has shown that in

healthy, well-nourished cattle the natural cycle of coat changes is photo-periodically regulated. This finding, however, does not preclude the possibility that other environmental factors might also influence coat changes. Low nutrition impedes seasonal shedding, and the hair which is retained in the summer months appears lifeless and bleached (Yeates, 1958). It is suggested that the plane of nutrition influences shedding, though some individuals within the breed are less affected than others. There are two distinct varieties of coat retention--one of nutritional origin, the other inherent. The nature of inheritance and heritability of coat retention is of practical importance for selective breeding under thermal stress. It is best to select the early hair shedders, since they are the ones possessing a nutritional reserve at the end of the summer.

C. Drought Stress

Under normal conditions, the body water content of full-grown animals is remarkably constant, that is, the intake should equal the combined outgo in feces, urine, and evaporation by lungs and skin. The growing calf, the fattening steer, and the pregnant cow all need extra water to build up new tissues. Water requirements also depend on age, growth cycle, type of ration, frequency of watering, and environmental temperature. During droughts, the water content of pastures is very low, often less than 50 percent as compared with the 70 to 80 percent of well-watered pastures. Adverse effects of low water intake or consumption of saline water have been discussed (Leitch and Thompson, 1944-1945). Exact knowledge of water requirements for beef production under unfavorable environmental conditions is still lacking. The freezing-point depression and dry matter content of the different parts of the alimentary canal have been determined for temperate and tropical crossbreds (Quarterman et al., 1957). The osmotic pressures and dry matter content of the feces and of the large intestine are greater in the Brahman than in the crossbreds and may be connected, through water economy, with the greater tolerance of the Brahman to hot and dry conditions.

D. Cold Stress

Man has done less about cold climates than about tropical climates. Galloway and yak breeds and their crosses are very well suited to frigid conditions. In Canada, cold-resistant types have been evolved by hybridizing buffalo and cattle (Deakin et al., 1935). Cold-resistance is usually associated with higher basal metabolism and over-all heat production per unit surface area (Worstell and Brody, 1953). The thyroid gland can react quickly to cold climates. It is possible that the thyroid gland in cattle is stimulated during the cold night, then depressed during the warm day. What effect continual diurnal stimulation and depression has on thyroid function is not known, nor is the effect of high altitude understood.

Although the smooth-coated Brahman types can withstand the cold comfortably, they consume more feed than other breeds in order to maintain their heat balance at a temperature of 5° F.

The adverse effects of climatic stress on productivity in cattle have been demonstrated (Andrews, 1957; Bonsma, 1955; Brody, 1948, 1956; F.A.O., 1956; Findlay, 1950; Findlay and Beakley, 1954; Johansson et al., 1958; Lee, 1957; Lee and Phillips, 1948; and Roubicek, et al., 1957). The function of the sweat glands in relation to thermal regulation has been studied (Hafez et al., 1955b; Hafez and Shafei, 1955). Recent studies in Australia have been undertaken to evaluate the cutaneous evaporation losses in calves in relation to respiratory evaporative loss and skin and rectal temperatures (Taneja, 1958). The effect of cold stress on animal production has been discussed (Amschler, 1957).

II. Genetic Stress

An extensive nation-wide study has been carried out to evaluate the problems and practices of American cattlemen (Ensminger et al., 1955). The authors have reported that in the southern states the mortality rate (to weaning) was 50.6 percent in the Aberdeen-Angus and 26.4 percent in the Hereford. It is reasonable to suppose that some breeds of beef cattle are less genetically adapted to certain areas than are others.

The extent to which any breed succeeds under rigorous conditions is largely determined by their range of climatic tolerance, which is wider for some breeds than for others. To identify the individual whose heredity best adapts him to thrive under unfavorable conditions, it is necessary to expose him, or at least large samples of his sibs and progeny, to those unfavorable conditions. Crossbreeding between temperate breeds (Bos taurus, L.) and the Brahman humped breeds (Bos (Bibos) indicus, L.), also with the Afrikaner, has been undertaken in the coastal plains area at Jeanerette, Louisiana, in northern Queensland, Australia, and in the tropic states of South Africa. The findings indicate that crossbred calves are superior to calves of temperate breeds under comparable conditions. The percentage of tropical blood in crossbred stock is thus of considerable importance, and somewhere between 25 and 50 percent of blood is necessary to give compatibility to thermal stress. Further studies are needed to determine the proportion that can be expected to give the best results, particularly in a continuing breeding program. The difference in the weight between calves sired by Brahman and Afrikaner bulls is not so clear cut, but the averages are in favor of those sired by Brahman bulls (Bonsma, 1955).

Range cattle producers in the United States and Canada have been concerned with the "deterioration" in some of the beef breeds. It is claimed that range cattle today do not measure up to the ranchers' requirements. The cattle have become soft; their bones are smaller and more refined, they often lack a rugged constitution; and they are losing their ability to

rustle a living under difficult range conditions. This situation has led to the evolution of American beef breeds, the Santa Gertrudis, the Beefmaster, the Brangus, and the Charbray, by crossing the Brahman with the English breeds.

It is emphasized here that antagonisms may result between the several production factors for which we are simultaneously selecting. Studies in hot climates of the grazing habits of temperate and tropical cattle and their crosses have shown differences in heat tolerances under field conditions. The grazing times of the animals are related to the amount of tropical blood present, being greatest in the tropical cattle and least in the temperate breeds. Brahman X Hereford crosses make better summer gains, while Herefords make greater and cheaper total gains (Ittner et al., 1954). Carcasses of the crosses have more bone and less fat, principally because of less finish (Carroll et al., 1955). Brahman crossbreeds yield 2 to 4 percent more than Herefords and Shorthorns (Black et al., 1934). Brahman bulls imported from America into Australia have a greater volume of sweat glands and greater heat tolerance than Australian born Shorthorns or Scotland-imported Shorthorns (Nay and Dowling, 1957). There is a close correlation between the sweat gland density and heat tolerance coefficient. The r value ranges from +0.1953 at one year to +0.3127 at four years and over, (Walker, 1957).

Although the domestic beef cattle and bison have been hybridized experimentally, the sterility of male hybrids has prevented the development of a breed of cattle. Cattle infertility has been studied in relation to intratesticular temperature (Peters and Newbound, 1957).

III. Managerial Stress

Productivity in cattle is lowered by faulty management such as abuse, undue excitement, mixing large and small animals, shipping stress, overcrowding, cold and damp floors, faulty equipment, lack of feeder space, poor ventilation, and unsanitary conditions. Lack of space in group feeding stimulates competition between hungry cows. Timid animals are chased away. The effect of unfavorable management on growth rate, mortality, incidence of disease, and milk yield has been demonstrated in temperate breeds reared in Brazil (Carneiro and Lush, 1954).

IV. Nutritional Stress

The effect of nutritional stress upon cattle depends on four factors, (1) the exact nutritive lack, (2) length of time that the deficiency continues, (3) age of the animals, and (4) the prevailing environment. The birth weight is markedly affected by nutritional stress (Joubert and Bonsma, 1957). The effects of the level of nutrition during growth upon body size, conformation, fertility, and longevity, have been demonstrated (Series of articles published by Ruakura Station, New Zealand; Cornell University, Rowett Institute, Scotland) and reviewed (Brumby, 1958). The

caloric intake of rations is not the only limiting factor of production. Productivity can be adversely affected by a deficiency of minerals, trace elements, or vitamins. Mineral deficiencies in problem areas have been reviewed (Lundell and Derby, 1955).

It is known that plants are no better than the soils on which they grow, and animals are no healthier than the plants that nourish them. Boggy and other soils deficient in copper or high in molybdenum make copper unavailable to cattle. Unpalatable pasture does not appeal to grazing cattle; this affects grazing, rumination ratio, and thus the pounds of beef produced per acre. The botanical composition of pasture, presence of luscious weeds, and droppings, all affect the efficiency of grazing. In several areas, beef cattle rely almost entirely upon pasture for food. Such a situation complicates conventional rationing schemes and feed consumption estimates. By the use of the chromium oxide fecal marker and nitrogen digestibility technique (Wallace, 1956), it should be possible to derive general equations relating intake of pasture to body size and live weight gains.

The discussion of nutritional stress on productivity will be restricted here because of limited space. The effects of nutritional imbalances on reproductive ability will be discussed under a separate heading.

It is commonly held that the animal which loses weight when on pasture nursing a calf is a good cow because she has a lot of milk. This is not true and it is advisable to breed only from those cows which show a small weight loss at weaning. It can be argued that to raise a heavy calf these cows must have milk and at the same time they must be more adaptable than the others to maintain their weight in doing so.

The plane of nutrition affects the age at eruption of permanent incisors; this fact should be considered while estimating age from dental development. Under low plane of nutrition, deciduous incisors wear rapidly; this is not the case in regard to the permanent incisors (Joubert, 1956).

V. Disease Stress

In torrid regions, parasitic infestations (especially ticks and stinging flies) cause great irritation and discomfort to cattle. Infestations are also responsible for the spread of diseases such as piroplasmosis, anaplasmosis, and rickettsiosis. No matter how virulent the infection or how high the mortality, natural selection will develop individuals that are resistant to it. These survivors will reproduce, and with reduced population density, percentage survival of the offspring will be greater. Soon the population will be returned to numbers that are normal for the breed within the limits of the environment. The resistance to ectoparasites under unfavorable environments varies with the breed (Ullea and Alba, 1957). Studies with monozygotic twin pairs have shown similarity in the susceptibility to

bloat (Hancock, 1953), yet the similarity in fecal egg count and titre response to Brucella abortus vaccine is less marked (Hancock, 1952).

There are statistically significant differences between bulls in the proportion of tuberculin-positive and tuberculin-negative animals amongst their daughters (Rognoni, 1957). Brahman bulls imported into Central Africa from Texas are more susceptible to skin infections than those imported from the Norris Ranch, Florida (Mandon, 1957).

The malnourished animal is the first to become the prey of internal and external parasites. Internal and external parasites can be partially overcome in either of two ways. The first, which is preferable, is to breed adapted animals with short hair, smooth coats, and thick movable hides to make them tick repellent. It would, however, be unadvisable not to use the protective measures science has provided in the form of dips, deworming remedies, and therapeutic treatment against internal and external parasites. If there are successful methods of combating disease by immunization or by therapeutic treatment, they should be employed, but these methods should not become the major issue in cattle breeding operations. They must be used only to overcome certain problems.

Fertility of Cattle Under Unfavorable Environments

A quantitative evaluation of reproductive performance was recently devised by members of the U. S. Dairy Husbandry Research Branch who measured the tendency of daughters to reproduce at the same level (high or low) as their dams. Although indications of genetic influence were positive, the results were not statistically significant. Also, results from other sources have shown that the repeatability and heritability of some reproductive functions are extremely low and that the environment exerts major influences on fertility levels.

The adverse effect of unfavorable environment on fertility can be exerted via the gonads, accessory sex organs, or the endocrine system. Climatic effects have been reported for the weight of the gonads, accessory reproductive organs, endocrine glands, hormone output (Beer and Meyer, 1951), and the histochemistry of testis and sperm. Certain enzyme systems associated with the reproductive function may affect one of the following: (1) the sensitivity of the gonads to the circulating gonadotropins, (2) the output of gonadotropins, and/or (3) the balance between FSH and L.H. The thyroid activity may also be involved.

Studies on TDN and feed intake in dairy cattle provide no basis for the earlier and long-held belief that the fertility of the germ cells may be seriously impaired by uncommonly high or low feed (N-E.R.P., 1957). Likewise, the results with low trace-mineral content rations and rations with different qualities of protein for young breeding bulls support this conclusion. In contrast to these findings, it is equally clear that the onset of heat

and ovulation in young heifers and of semen production in young bulls is definitely and positively correlated with the level of nutrient intake and rate of body growth.

The following is a discussion of certain specific effects of environmental stresses on female and male fertility.

A. Female Fertility

Lowered fertility of temperate breeds in the tropics is probably due to the thermal stress causing increased body temperature and inhibition of the anterior pituitary functions in the young calf. The duration of estrus is shortened when the monthly average temperature is over a certain threshold; this is one cause of increased services per conception. Transplantation experiments using psychrometric rooms have demonstrated that high environmental temperature interferes with uterine physiology rather than the fertilized ovum. The effect of unfavorable daylength environment is not pronounced in cattle as in sheep where "summer sterility" occurs at high latitudes in both sexes. Lack of sunlight for successive generations is not detrimental to reproductive performance (McDiarmid et al., 1956).

Heifers on low phosphorus intake show varying signs of estrus during diestrus and clear-cut symptoms of estrus when the intake of phosphorus is optimal. This observation is very important when artificial insemination is used. Cows may be inseminated at the wrong time with consequent poor conception, or even the setting up of pyometra as a result of the sensitivity of the cervix during the luteal phase. The influence of mineral imbalances on the susceptibility to genital infection is well known. Infection with Trichomoniasis and Corynebacterium pyogenes could not be established when animals are provided with more phosphorus than calcium, but when this is reversed, infection could be established (Hignett, 1956). The effect of feeding in relation to genital vibriosis is not known, but a possible connection cannot be ruled out.

Vitamin D affects female fertility (Hignett and Hignett, 1953; Abrams, 1952). The maintenance of a satisfactory vitamin D status minimized the influence of calcium and phosphorus intake on fertility. Unfortunately, maintenance of a satisfactory vitamin D status can be difficult when consumption of carotene is high. If animals lack vitamin D, one should endeavor to feed phosphorus liberally and calcium well in excess of phosphorus (Hignett, 1956). Low carotene diet for two generations increases the frequency of stillbirth and causes pituitary cysts (Byers et al., 1956). The administration of α -tocopherol acetate for five weeks after calving does not affect the intensity of estrus, the interval between calving, or fertility (Fogdegard, 1956).

Crowded barns, chaining, hard flooring with insufficient straw, driving along hard roads, transportation, stress, and pain inhibit estrus reflexes.

Unfavorable environments increase the frequency of silent heat, infantile ovaries (Asdell, 1949), short estrus, and cystic ovaries. These conditions are regarded as adaptive sterility which is associated with hyperfunction of the adrenal cortex and with hormonal imbalance. Such hormonal imbalances have been discussed in relation to cystic follicular degeneration (Schaetz, 1956).

B. Male Fertility

The effect of environment on semen qualities has been extensively investigated (Lewis, 1948; Mercier and Salisbury, 1947; Phillips et al., 1943). The available material for comparing the findings of different workers differs considerably with respect to age, breed, nutrition level, and size of sample. It is therefore impossible to assess how much of the difference in the results thus obtained was due to unfavorable environment and how much to other factors. In dairy bulls, experimental increase of temperature decreased semen motility and concentration; a reduction in temperature increased ejaculate volume (Casady et al., 1953). Protein deficiency, overconsumption of water, and vitamin A deficiency have adverse effects on sex drive. In monozygotic bull calves the low plane of nutrition causes a delay of 4 months in the appearance of fructose and citric acid in the semen, and of 1 month in the appearance of first spermatozoa (Mann and Rowson, 1956); this has certain effects on the fertilizing capacity.

The influence of management upon sexual performance has been studied, using monozygotic twin bulls (James, 1953; Bane, 1954). Bulls used excessively as yearlings show poorer sexual performance as three-year-olds than their co-twins moderately used in their first reproductive season. The inhibitory sexual reflexes in bulls are detrimental to their fertility. In natural breeding, such reflexes develop as a result of distraction during coitus (shouting, noise, irritations, or fright), unsatisfaction after copulation (withdrawal from cows after mating), cruel handling, or painful medication. During semen collection, sex drive and semen qualities are affected by wrong techniques of applying the artificial vagina (such as temperature, angle, time of application in relation to penis erection) or rough withdrawal of the artificial vagina. The effects of managerial stress have been reviewed in relation to inhibitory reflexes (Bonadonna, 1956; Parashutin, 1956; Hafez, 1958). The effects of different environmental conditions on fertility and adaptive sterility have been discussed (Hafez, in press). More attention should be paid to reflex-promoting and -inhibiting factors in planned breeding.

The different stress factors which affect productivity and fertility in cattle are shown diagrammatically (Figure 2).

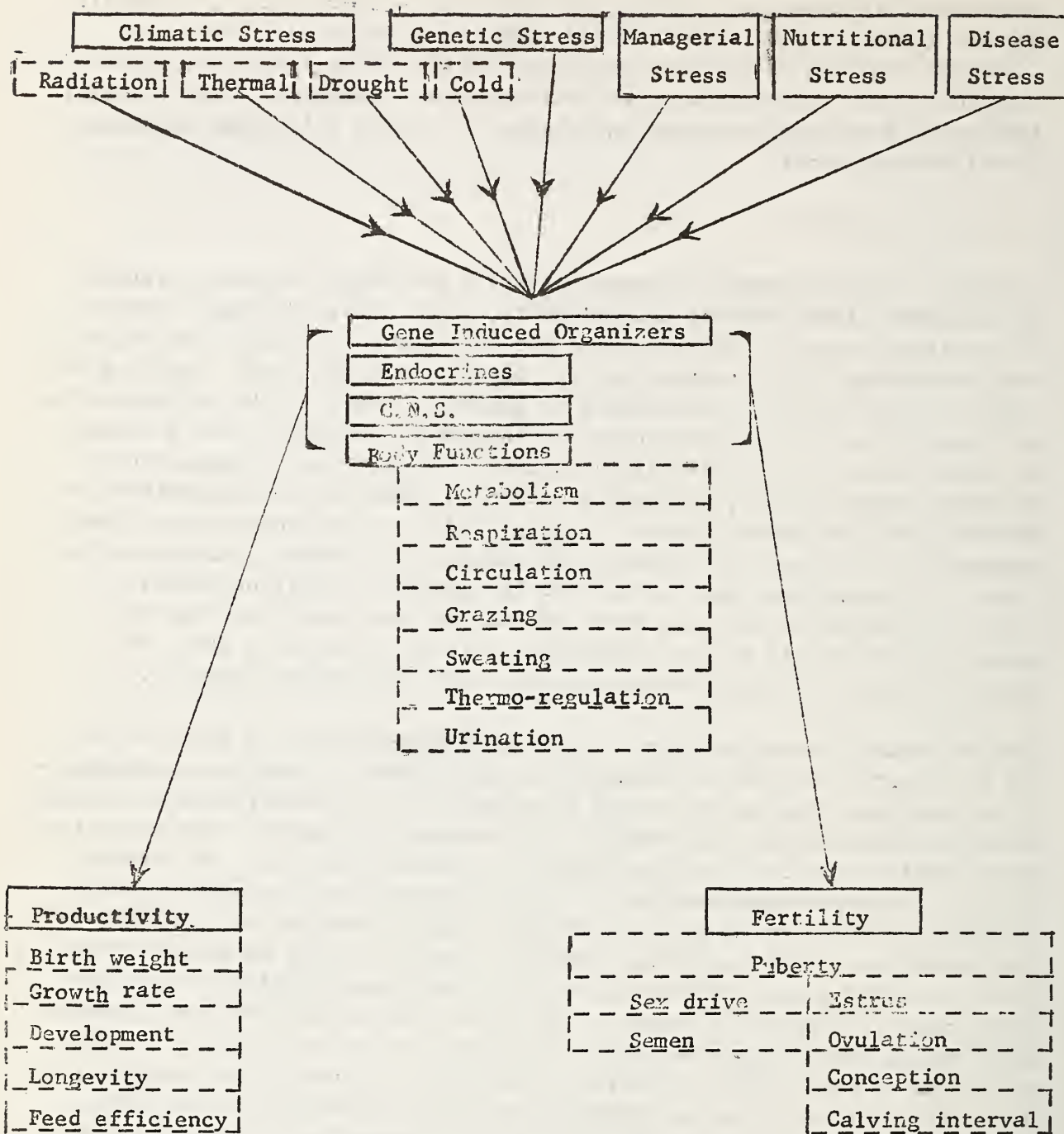


Figure 2.--Factors and mechanisms by which the unfavorable environment affects productivity and fertility of cattle.

Recommendations

1. Improving the Environment

In every locality, substantial improvement in the productivity of cattle can be obtained by improving the environment. The cost and the value of the increased products that would result must be considered, of course. Restrictions laid down by nature limit the extent to which such improvements are economically sound.

a. Management and Nutrition

For the most economical production, maximum use must be made of range and pasture lands. Management practices should be so designed that the maximum yield of animal products is obtained per unit of land. Winter feed supplies must be provided by harvesting and storing hay, silage, or other roughage, or by reserving winter grazing areas. Supplemental feeding of salt and also of certain other minerals may be necessary in order to avoid deficiencies. Adequate calories should be provided in a well-balanced ration because much feed is wasted by inefficient use of unbalanced rations. Disease and parasites must be controlled if production is to be carried out efficiently. Provision for shade in open pastures, rotation of grazing sites with changing weather conditions, moderation of feeding levels in the hottest season, and spray cooling are all procedures which relieve stress conditions.

b. Shelters

Light as such cannot be readily controlled. However, when fattening cattle it is advisable to keep their stables as dark as possible, because this reduces the incidence of flies and ticks, which in turn will influence the amount of feed the cattle consume. Restricted movement will also result in more efficient feed utilization.

More trees should be planted or shelter provided for animals to enable them to find shade and thus avoid the problem of infra-red radiation. In a hot climate, radiant heat energy absorbed by the body must be dissipated before the animal can consume sufficient feed for maximum growth.

c. Ventilation

The primary object of ventilation is to produce conditions which give optimum comfort and allow optimum productivity. In temperate areas, we should prevent the undue accumulation in the barn of the heat and water vapor dissipated by the animals. In hot areas, we should overcome the adverse effects of thermal stress by providing a uniform climate. The design of well-ventilated barns represents the final stage of the application of bioclimatological studies to the rational housing of cattle. The term "air-conditioned cattle house" is appearing frequently in the farm press. The

systems used for the most part involve the cooling of air with conventional air-conditioning equipment. It should be pointed out that the circulation of large amounts of air in cattle buildings is usually accompanied by increasing quantities of dust. Dust may affect the operation of the cooling equipment, may irritate the animals, or may carry disease-producing organisms.

It may be acceptable to use water as a cooling agent for growing heifers. It is emphasized that water need not be applied in quantity. Coarse sprays with an accumulation of ground water create problems of mud, and possibly, sanitation. The application of water as a mist sufficient to dampen the animals cools them without excessive run-off. Sprays can be controlled to operate intermittently by thermostats or time clocks.

2. Improving the Cattle

The possibility of improving the cattle must also be considered in long-range breeding programs. This is achieved by either of two methods.

a. Selection for Adaptability

Cattle must be bred for adaptability, which implies that they should be able to utilize pastures efficiently. Without adaptability, selection of cattle on a weight-for-age basis has little purpose. Experience has shown it is essential that selection and breeding for improvement be founded on ecological principles. The cattle breeder must, therefore, try to correlate the morphological and physiological characteristics of the indigenous stock with the more important environmental factors in order to establish the basis for selection.

In areas of high atmospheric temperature, a short, sleek, dull coat is of great value, for it enables the animal to dissipate excess heat. Dull coats are made up of outer protective hair and an inner heat-retaining coat of thin nonmedullated hair. Hair samples taken from such cattle, when moistened and rubbed between the hands, felt into a tight mass.

In areas of high solar radiation or exposed areas, cattle should possess abundant glossy pale hairs and thick pigmented hides. In Herefords, epithelioma of the eyelids can be prevented almost entirely by breeding only from those individuals which have a ring of red hair around the eyes, and pigmented eyelids. Hereford cattle are classified into three groups (Bonsma, 1949) according to the amount of pigmentation^{on} the eyelids and on the surrounding hair: 1. pigment almost or entirely absent; 2. pigment or broken pigment on the eyelids accompanied by a small, often interrupted, ring of brown hair less than 1/2 inch wide around the eyes; and 3. a large ring at least half an inch wide around the eyes. The use of bulls with pigment around the eyes increases the proportion of cattle with pigment on those parts.

If it is known how to select animals which utilize feed efficiently, these will be the ones which will survive when feed becomes scarce. These animals have certain common characteristics, such as good stomach capacity and the ability to walk easily. They are always smooth coated and have no difficulty in overcoming high temperatures. They also have good, broad, strong muzzles.

Scientifically designed records should be used. The sire exerts an effect, even on the relative evaporation rate from the skin (Berman, 1957). Trained men are needed to develop, through selection within existing cattle breeds, strains which are better adapted to environments, which can approach the normal productivity readily obtained in more favored localities. In performance testing under the unfavorable environments, we should establish new factors for correcting production according to age, month of calving, etc.

The selection for disease-resistant strains is of considerable practical importance.

b. Developing Adaptable Breeds

Developing new breeds to fit unfavorable environments is an important aspect of animal breeding in several localities. Both the difficulties and the possibilities must be fully recognized. Many breeds of cattle have been developed, but they vary widely in traits and adaptability. Sometimes, circumstances arise in which no one of the existing breeds meets all the requirements of the breeder. Under such circumstances, it may be desirable to develop a new breed, combining characteristics of two or more breeds.

At the Iberia Livestock Experiment Farm near Jeanerette, Louisiana, the U. S. Department of Agriculture has been testing new lines of cattle containing varying amounts of Brahman and Aberdeen-Angus blood. Similar work is recommended for other localities. The development of a new breed is not a task to be undertaken lightly. A definite need for a new type should be clearly evident before such a project is started. Facilities should be available to handle a large number of animals and to continue the project for many years, so that the new types can be well established. Those planning and supervising the work should clearly understand the genetic principles involved.

New breeds of beef cattle suited to unfavorable environments could be produced much faster if a large number of breeding centers with comparable climates would concentrate on the same cross. Then the centers could exchange breeding stock and so avoid the inbreeding which is certain to occur in a small unit. This technique will apply to developing breeds adapted to thermal or cold stress. New breeds may be developed for high altitudes or to climates characterized by sudden changes in the diurnal

and seasonal temperatures. In Norway, the Hereford, the Dole, and the Norwegian Red-and-White are inter-bred to improve carcass quality and to build up cold resistance (Skjervold et al., 1956).

Future Research

Unfavorable environment acts on productivity indirectly by way of poor nutrition and transmissible disease which mask to some extent the direct effects on the physiological well-being of cattle. As these two factors come under control, the direct effects become proportionally more important.

1. Building Research

The translation of physiological requirements to building design is a task for building research. Such research would deal with designing low cost material for building well-ventilated animal shelters to accommodate more cattle. This is complicated by two facts: the exceptionally large per capita output of expired air with cattle, and the fact that large air inlets or outlets in the walls or roof are peculiarly susceptible to changes in external wind direction or velocity.

2. Grassland Research

Many of the individual species of grass are not in themselves of considerable forage importance, but they play various parts in maintaining the balance essential to a good range. As a group, the grasses have very peculiar reproductive patterns. There is every reason to believe that we can learn enough about the relationship between genetic constitution and desirable features to synthesize new species or types of grass which in a given environment will be more nutritious than the plants we now have. In this respect, long-range programs with an ultimate goal seem desirable.

It is well established that as we breed more productive cattle, the ones that consume more grass are the ones that make more rapid gains. Improvement in pastures needs to go hand in hand with improvement in cattle

3. Bioclimatology Research

The first step in obtaining techniques for establishing and maintaining desirable breeds suitable to unfavorable environment is to discover the physiological effects of the different environmental factors where the animal lives. Unfavorable environments affect the nervous and endocrine systems to a marked degree and produce changes in the composition of the body fluids. Endocrinological and biochemical studies will be vital to work in bioclimatology. To take but a few instances, knowledge is lacking concerning the effect of increased ventilation on the acid-base balance of the blood and the specific biochemical mechanism, if any, which preserves

this balance in face of CO₂ depletion. Practically no work has been done on renal function in cattle or on the effects of increased temperatures on alimentary function or appetite.

4. Animal Reproduction

Most of the experimental work on animal reproduction has been carried out on dairy cattle. The physiological requirements of lactation vary from those of growth production. Therefore, it is suggested that the response of beef cattle to environmental stress may be different from that of dairy cattle. For example, high milk production in dairy breeds involves considerable calcium-phosphorus turnover, with which vitamin D is closely linked. At high latitudes where sunshine is relatively weak, beef breeds are less susceptible to avitaminosis D than dairy breeds. Moreover, no critical work along these lines has been undertaken in psychometric rooms. The effects of radiation, thermal, and cold stress on conception rate, prenatal development, and sterility (mainly embryonic mortality) are still obscure. Here again, the diurnal variations in weather are emphasized.

5. Cooperation of trained men from a variety of scientific fields is needed to maintain the best possible animal growth curves for particular areas. The fields include grassland improvement, better selection of native species of forage plants, range management, water development, supplemental feeding, and husbandry practices. A system for the more efficient exchange of information between different states as well as between different countries could be organized.

Summary

1. Healthy high-producer animals are in delicate balance with the fluctuating environment. Compatability is a complex phenomenon that cannot be reduced to a single type of measurement. Compatability is well illustrated by the anatomical adjustment of the animal.
2. Unfavorable environments include climatic stress, faulty management, unbalanced nutrition, genetical incompatibility, and disease susceptibility. Stress is manifested in three stages--alarm, resistance, and exhaustion. The differential effect of unfavorable environment on the value of the different breeds is illustrated graphically.
3. The stress effect of radiation is modified by the morphological characteristics of coat, pigmentation, and skin properties (thickness, absorptivity, conductivity, and elastic properties). Beyond a certain threshold level of exposure, pathological conditions such as injuries, cancers, epithelioma, and facial eczema occur.

4. Diurnal variation of rectal temperature in calves is a valuable indication of thermal tolerance. Environmental temperature affects blood cholesterol and thyroid function. The heat regulatory mechanism is not well developed at birth. Topography should be considered in assessing the thermal effects of the environment.

Body water requirements under thermal stress are not exactly known.

5. Little is known about cold resistance in cattle. The effect of intermittent cold nights and hot days on the thyroid function is possibly involved in cold resistance.
6. Short-term crossbreeding between temperate and tropical breeds of cattle with 25 to 50 percent of tropical blood gives maximum tolerance to thermal stress. Best proportions of blood for a continuing breeding program are unknown. Genetic improvement for unfavorable environments does not always lead to improvement in all of the productive characteristics such as grazing ability, dressing percentage, lean:fat:bone ratio, and fertility.
7. Faulty management or housing, and shipping stresses reduce growth and lactation and increase mortality and disease susceptibility.
8. The effect of nutritional stress varies with the type and period of deficiency, the age of the animal, and the prevailing environment. The grazing:ruminant ratio and the botanical composition of pasture are involved.
9. In underdeveloped areas, parasites cause discomfort and spread disease.
10. The effect of environment on fertility overrides heredity. TDN, feed intake, and trace elements affect sexual development, but not the germ cells. Mineral imbalances increase susceptibility to genital infections. The interaction between vitamin D and carotene intakes affects reproduction. The damaging effect of thermal stress is apparent in the uterine physiology rather than the fertilized ovum. Lack of sunlight is not detrimental to reproduction.
11. Unfavorable environments affect certain semen characteristics more than others. The inhibitory sexual reflexes are discussed in relation to planned breeding.
12. Improving the environment has been discussed in relation to management, nutrition, and ventilation systems. Principles of selection of cattle for areas of thermal stress or radiation stress have been outlined. Development of new breeds can be speeded up by exchange of breeding stock between centers of comparable environments.
13. Future research work in buildings, grassland, bioclimatology, and animal reproduction is suggested.

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A SOLUTION OF ADDITIVE GENETIC, MATERNAL, SPECIFIC,
AND SEX LINKAGE EFFECTS ON WEANING WEIGHTS OF HEREFORD CALVES

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George O'Brien (1956) utilized the least squares procedure as outlined by Henderson (1948) in evaluating additive genetic (g), maternal (m), specific combining ability (s), sex linkage (r), and sex (a) effects on weaning weights of Hereford calves. Before developing the thesis, O'Brien worked out the following example of a solution for these unknowns using a limited sample of data. The example has been checked and may serve as a useful guide to those wishing to develop constants from the solution of simultaneous equations involving large numbers of unknowns. Simultaneous equations were solved in this case by iteration. This type of computation, tedious by nature, is often solved using appropriate programming of electronic computers.

Appropriate sums of squares for the effects are shown also by the reduction method.

The problem was to attempt to determine the effects on weaning weight of crossing inbred sires from various Hereford lines at Fort Lewis on line-cross cows in the same herd. It is important to learn if variation in weaning weights of calves herein was due primarily to additive or specific combining effects. It was possible in the analysis, as well, to isolate that part due to the mothering of the calf aside from the genetic makeup (additive and specific) of the calf itself.

The additive and specific estimates were based on line of sire of the calf and interaction between line of sire and line of dam's sire, respectively. Maternal effects were estimated from the line of the dam's sire. Sex linkage effects were estimated from reciprocal crosses considering additive, specific and maternal effects. In O'Brien's thesis, errors have been found in the variance analysis and in the estimates. These are in the process of correction before publication. The following problem outline has been checked and appears correct.

TABLE I
Subclass Numbers

Line of Sire	Line of Dam									
	BA (1)		FL (2)		R (3)		SJ (4)		Sum	
	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2
1 BA	0	0	2	1	5	2	1	7	8	10
2 FL	1	3	0	0	2	2	0	0	3	5
3 R	0	1	2	2	0	0	4	2	6	5
4 SJ	0	1	0	2	2	3	0	0	2	6
Sum	1	5	4	5	9	7	5	9	19	26

$\frac{1}{2} A = \text{Sex}$

$\Sigma = 45$

TABLE II
Subclass Sums

Line of Sire	Line of Dam									
	(1) BA		(2) FL		(3) R		(4) SJ		Sum	
	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2
1 BA	0	0	947	485	2507	967	494	3421	3948	4873
2 FL	419	1327	0	0	832	833	0	0	1301	2160
3 R	0	451	859	882	0	0	1723	839	2582	2172
4 SJ	0	461	0	852	827	1188	0	0	827	2501
Sum	419	2239	1806	2219	4216	2988	2217	4260	8658	11706

$\Sigma = 20364$

$$R(T) = \sum_{ijkl}^2 = 9378090$$

TABLE III
Equations for R ($\mu, \epsilon, m, s, r, a$)

		$\tilde{r}_{ij}$													Sum	$\tilde{r}_{ij}$ estimates	
	a_k	Sex 1	Sex 2	12	13	14	21	23	24	31	32	34	41	42			43
Sex 1	19	-	-	2	5	1	1	2	0	0	2	4	0	0	2	8658	3.27351
Sex 2	-	26	26	1	2	7	3	2	0	1	2	2	1	2	3	11706	-3.27351
$\tilde{r}_{ij}$ 12	2	1	1	3												1432	474.05982
13	5	2	2		7											3474	494.88278
14	1	7	7			8										3915	491.83013
21	1	3	3				4									1746	438.13676
23	2	2	2					4								1715	424.75000
24	0	0	0						0							-0-	-
31	0	1	1							1						451	454.27351
32	2	2	2								4					1741	435.25000
34	4	2	2									6				2562	425.90883
41	0	1	1										1			461	464.27351
42	0	2	2											2		852	429.27351
43	2	3	3												5	2015	410.85470

$\tilde{r}_{ij}$ is symbol for combining the effects of μ, ϵ, m, s, r , omitting "a" effect.

Tests of Hypotheses

(1) $r_{ij} = 0$

$R(\mu, g, m, s, r, a) = R(\text{Reciprocal Crosses}, a)$ where $\tilde{r}_{ij} = \mu g_i + m_j + s_{ij} + r_{ij}$

TABLE IV
Absorbing Reciprocal Cross Coefficients

$\tilde{r}_{ij}$	a_1	a_2	Sum
12	2 (.66667)	1 (.33333)	1432
13	5 (.71428)	2 (.28571)	3474
14	1 (.12500)	7 (1.87500)	3915
21	1 (.25000)	3 (.75000)	1746
23	2 (.50000)	2 (.50000)	1715
24	0 (-----)	0 (-----)	-0-
31	0 (-----)	1 (1.0000)	451
32	2 (.50000)	2 (.50000)	1741
34	4 (.66667)	2 (.33333)	2562
41	0 (-----)	1 (1.0000)	461
42	0 (-----)	2 (1.00000)	852
43	2 (.40000)	3 (.600000)	2015

$\Sigma = 20364$

TABLE V

Equations for $R(\mu, g, m, s, r, a)$ with $\tilde{r}_{ij}$ absorbed

	a_1	a_2	Sum
a_1	8.25358	-8.25353	+54.03630
a_2	-8.25357	8.25359	-54.00156
$a_1 a_1$	$= 19 - 2(.66667) - 5(.71428) \dots$ $= 19 - 10.74642 = 8.25358$		$-2(.400000)$
$a_1 a_2$	$= -2(.33333) - 5(.28571) \dots \dots -2(.600000) = -8.25353$		
$a_2 a_2$	$= 26 - 1(.33333) - 2(.28571) \dots \dots -3(.60000) = 26 - 17.74641 = 8.25359$		
$a_2 a_1$	$= -8.25357$		
Sum associated with a_1	$= 8658 - 1432(.66667) - 3474(.71428) \dots - 2015(.4000) =$ $8658 - 8603.96370 = +54.03630$		
Sum associated with a_2	$= 11706 - 1432(.33333) - 3474(.28571) \dots - 2015(.600000) =$ $11706 - 11760.00156 = -54.00156$		

Since $a_1 + a_2 = 0$, the a_2 equation can be deleted and the a_2 coefficient can be subtracted from the a_1 coefficient in the a_1 equation

$$16.50716 a_1 = +54.03630$$

$$a_1 = 3.27351$$

$$a_2 = -3.27351$$

Substituting these for a_k in the equations of Table III

$$\begin{aligned} \frac{\Lambda}{r}_{12} &= 1/3 [1432 - 2(3.27351) - 1(-3.27351)] \\ &= \frac{1432 - 6.54702 + 3.27351}{3} = \frac{1428.72649}{3} = 476.24216 \end{aligned}$$

$$\begin{aligned} \frac{\Lambda}{r}_{13} &= 1/7 [3474 - 5(3.27351) - 2(-3.27351)] \\ &= 1/7 [3474 + (-16.36755) + 6.54702 = -9.82053] \\ &= \frac{3464.17947}{7} = 494.88278 \end{aligned}$$

$x = 3.27351$ in the subsequent computations

$$\begin{aligned} \frac{\Lambda}{r}_{14} &= 1/8 [3915 - 1(x) - 7(-x)] \\ &= 1/8 [3915 + 19.64106] \\ &= \frac{3934.64106}{8} = 491.83013 \end{aligned}$$

$$\begin{aligned} \frac{\Lambda}{r}_{21} &= 1/4 [(1746 - 1(x) - 3(-x))] \\ &= 1/4 [1746 + 6.54702] \\ &= \frac{1752.54702}{4} = 438.13676 \end{aligned}$$

$$\frac{\Lambda}{r}_{23} = 1/4 [1715 - 2(x) - 2(-x)] = 428.75$$

$$\frac{\Lambda}{r}_{24} = 0$$

$$\frac{\Lambda}{r}_{31} = \frac{1}{1} [451 - 0(x) - 1(-x)] = 454.27351$$

$$\frac{\Lambda}{r}_{32} = 1/4 [1741 - 2(x) - 2(-x)] = 435.25000$$

$$\begin{aligned}\frac{\Lambda}{r}_{34} &= 1/6 [2562 -4(x) -2(-x)] \\ &= 1/6 [2562-6.54702] \\ &= \frac{2555.45298}{6} = 425.90883\end{aligned}$$

$$\begin{aligned}\frac{\Lambda}{r}_{41} &= \frac{1}{1} [461 -0(x) -1(-x)] = 464.27351 \\ \frac{\Lambda}{r}_{42} &= 1/2 [852-0(x) -2(-x)] \\ &= 1/2 [852 + 6.54702] \\ &= \frac{858.54702}{2} = 429.27351\end{aligned}$$

$$\begin{aligned}\frac{\Lambda}{r}_{43} &= 1/5 [2015 -2(x) -3(-x)] \\ &= 1/5 [2015 +3.27351] \\ &= \frac{2054.27351}{5} = 410.854702\end{aligned}$$

TABLE VI

Complete set of $\frac{\Lambda}{r}_{ij}$ estimates is:

12 = 474.05982	31 = 454.27351
13 = 494.88278	32 = 435.25000
14 = 491.83013	34 = 425.90883
21 = 438.13676	41 = 464.27351
23 = 424.75000	42 = 429.27351
24 = 0	43 = 410.854702

Reduction due to fitting parameters

$$\begin{aligned}&= 8658 (3.27351) + 11706 (-3.27351) + 1432 (476.24216) + \dots \\ &- \dots -2015 (410.854702) = 9271632.59087\end{aligned}$$

$R(\mu, g, m, s, a) = R(\text{Crosses}, m, a)$

TABLE VII
Least Squares Equations for $R(\mu, g, m, s, a)$

	$\widetilde{s}_{ij}$												Sum
	12	13	14	23	24	34	a_1	a_2	m_1	m_2	m_3	m_4	
12	7						3	4	4	3			3178
13		8					5	3	1		7		3925
14			9				1	3	1			8	4376
23				8			4	4		4	4		3456
24					2		0	2		2		0	852
34						11	6	5			5	6	4577
a_1	3	5	1	4	0	6	19	0	1	4	9	5	8658
a_2	4	3	8	4	2	5	0	26	5	5	7	9	11706
m_1	4	1	1				1	5	6	0	0	0	2658
m_2	3			4	2		4	5	0	9	0	0	4025
m_3		7		4		5	9	7	0	0	16	0	7204
m_4			8		0	6	5	9	0	0	0	14	6477

TABLE VIII
Computational Procedure for Absorbing $\widetilde{S}_{ij}$

$\widetilde{S}_{ij}$	a_1	a_2	m_1	m_2	m_3	m_4	Sum
12	3(.42857)	4(.57143)	4(.57143)	3(.42857)			3178(<u>3178</u>) 7
13	5(.62500)	3(.37500)	1(.12500)		7(.87500)		3925(<u>3925</u>) 8
14	1(.11111)	8(.88889)	1(.11111)			8(.88889)	4376(<u>4376</u>) 9
23	4(.50000)	4(.50000)		4(.50000)	4(.50000)		3456(<u>3456</u>) 8
24	0()	2(1.00000)		2(1.0000)		0()	852(<u>852</u>) 2
34	6(.54545)	5(.45454)			5(.45454)	6(.54545)	4577(<u>4577</u>) 11

$$\begin{aligned} \text{Coefficient } a_1 a_1 &= 19 - 3(.42857) - - - - - 6(.54545) \\ &= 19 - 9.79452 = 9.20548 \end{aligned}$$

$$\begin{aligned} a_1 a_2 &= -3(.57143) - 5(.37500) - 1(.88889) - 4(.50000) - 0(1.00000) - 6(.45454) \\ &= -9.20542 \end{aligned}$$

$$\begin{aligned} a_1 m_1 &= 1 - 3(.57143) - 5(.12500) - 1(.11111) \\ &= 1 - 2.45040 = -1.45040 \end{aligned}$$

$$\begin{aligned} a_1 m_2 &= 4 - 3(.42857) - 4(.50000) - 0(1.00000) \\ &= 4 - 3.28571 = .71429 \end{aligned}$$

$$\begin{aligned} a_1 m_3 &= 9 - 5(.87500) - 4(.50000) - 6(.45454) \\ &= 9 - 9.10224 = -.10224 \end{aligned}$$

$$\begin{aligned} a_1 m_4 &= 5 - 1(.88889) - 6(.54545) \\ &= 5 - 4.16159 = .83841 \end{aligned}$$

$$\begin{aligned} m_1 m_1 &= 6 - 4(.57143) - 1(.12500) - 1(.11111) \\ &= 6 - 2.52183 = 3.47817 \end{aligned}$$

" and so on

"

"

"

"

TABLE IX
Equations for R (u. g. m. s. a) with $\tilde{S}_{ij}$ absorbed

	a_1	a_2	m_1	m_2	m_3	m_4	Sum
a_1	+9.2054	-9.2054	-1.45040	+.71429	-.10224	+.83841	132.13753
a_2	-9.2054	+9.2054	+1.45040	-.71429	+.10224	-.83841	-132.13753
m_1	-1.45040	+1.45040	3.47817	-1.71428	-.87500	-.88889	-134.84690
m_2	+.71429	- .71429	-1.71428	3.71429	-2.0000	- 0 -	83.00454
m_3	-.10224	+.10224	-.87500	-2.0000	5.6023	-2.72725	-38.80458
m_4	+.83841	-.83841	-.88889	- 0 -	-2.72725	3.61618	90.69271

$$\begin{aligned} \text{Sum of } a_1 &= 8658 - 3178 (.42857) \\ &\quad - 4577 (.54545) = \\ &8658 - 8525.86274 = 132.13753 \end{aligned}$$

$$\text{Sum of } a_2 = 11706 - 11838.09176 = -132.09176$$

$$\begin{aligned} \text{Sum of } m_1 &= 2658 - 3178 (.57143) - 3925 (.12500) - 4376 (.11111) \\ &= 2658 - 2792.84690 = -134.84690 \end{aligned}$$

$$\begin{aligned} \Sigma m_2 &= 4025 - 3178 (.42857) - 3456 (.50000) - 852 (1.00000) \\ &= 4025 - 3941.99546 = 83.00454 \end{aligned}$$

$$\begin{aligned} \Sigma m_3 &= 7204 - 3925 (.87500) - 3456 (.50000) - 4577 (.45454) \\ &= 7204 - 7242.80458 = - 38.80458 \end{aligned}$$

$$\begin{aligned} \Sigma m_4 &= 6477 - 4376 (.88889) - 4577 (.54545) \\ &= 6477 - 6386.30729 = 90.69271 \end{aligned}$$

TABLE X

Reduced equations for R (μ , g, m, s, a), a_2 and m_4 deleted

	a_1	m_1	m_2	m_3	Sum
a_1	18.4108	-2.28831	-.12412	-.94065	132.13753
m_1	- 2.90080	4.36706	-.82539	.01389	-134.84690
m_2	1.42858	-1.71428	3.71429	-2.00000	83.00454
m_3	- .20448	1.85225	.72725	8.32955	-38.80458

Iterative solution of these equations (first round)

$$(18.4108) a_1 = 132.13753$$

$$a_1 = 7.17772$$

$$(-2.90080) (7.17772) + (4.36706) m_1 = -134.84690$$

$$- (+4.36706) m_1 = -114.02577$$

$$m_1 = -26.11042$$

$$(1.42858) (7.17772) + (-1.71428) (-26.11042) + (3.71429) m_2 = 83.00454$$

$$+10.25395 + 44.76057 + (3.71429) m_2 = 83.00454$$

$$(3.7142) m_2 = 27.99002$$

$$m_2 = 7.53595$$

$$(-.20448) (7.17772) + (1.85225) (-26.11042) + (.72725) (7.53595)$$

$$+ (+8.32955) m_3 = -38.80458$$

$$-44.35021 + (8.32955) m_3 = -38.80458$$

$$(8.32955) m_3 = 5.54563$$

$$m_3 = .66578$$

TABLE XI
Tentative Iteration Values

	a_1	m_1	m_2	m_3
	0	0	0	0
1	7.17772	-26.11043	7.53595	.66573
2	4.01598	-26.78339	8.79741	.62873
3	3.93832	-26.60143	8.89365	.57690
4	3.95956	-26.56897	8.87492	.57184
5	3.96321	-26.57007	8.86785	.57278
6	3.96312	-26.57147	8.86778	.57369

Then the least squares estimates of the a 's and m 's are as follows:

$$\begin{aligned}
 a_1 &= 3.96312 & m_1 &= -26.57147 \\
 \text{and } a_2 &= -3.96312 & m_2 &= 8.86778 \\
 \text{since } a_1 + a_2 &= 0 & m_3 &= .57369 \\
 & & \text{and } \dots m_4 &= 17.14316
 \end{aligned}$$

Since

$$\begin{aligned}
 .83841 (3.96312) + (-.83841) (-3.96312) + (-.88889) (-26.57147) \\
 + 0 (8.86778) + (-2.72725) (.57369) + (3.61618) m_4 &= 90.69271 \\
 +28.69996 + (3.61618) m_4 &= 61.99275 \\
 m_4 &= 17.14316
 \end{aligned}$$

Substituting these estimates into equations in Table VII:

$$\begin{aligned}\frac{\Lambda}{s_{12}} &= 1/7 [3178 - 3(3.96312) - 4(-3.96312) - 4(-26.57147) \\ &\quad - 3(8.86778)] \\ &= 1/7 [3178 - 11.88936 + 15.85248 + 106.28588 - 26.60334] \\ &= 1/7 [3178 + 83.64566] = \frac{3261.64566}{7} = 465.94938\end{aligned}$$

$$\begin{aligned}\frac{\Lambda}{s_{13}} &= 1/8 [3925 - 5(3.96312) - 3(-3.96312) - 1(-26.57147) \\ &\quad - 7(.57369)] \\ &= \frac{3925 + 14.62940}{8} = 492.45368\end{aligned}$$

$$\begin{aligned}\frac{\Lambda}{s_{14}} &= 1/9 [4376 - 1(3.96312) - 8(-3.96312) - 1(-26.57147) \\ &\quad - 8(17.14316)] \\ &= \frac{4376 + 82.83197}{9} = 477.01867\end{aligned}$$

$$\begin{aligned}\frac{\Lambda}{s_{23}} &= 1/8 [3456 - 4(3.96312) - 4(-3.96312) - 4(8.86778) \\ &\quad - 4(.57369)] = \frac{3456 - 37.76588}{8} = 427.27926\end{aligned}$$

$$\begin{aligned}\frac{\Lambda}{s_{24}} &= 1/2 [852 - 2(-3.96312) - 2(8.86778)] \\ &= 1/2 (852 - 9.80932) = 421.09534\end{aligned}$$

$$\begin{aligned}\frac{\Lambda}{s_{34}} &= 1/11 [4577 - 6(3.96312) - 5(-3.96312) - 5(.57369) - 6 \\ &\quad (17.14316)] \\ &= 1/11 [4577 - 109.69053] = 406.11904\end{aligned}$$

$$\text{i.e. } \overline{s}_{12}^{\Lambda} = 465.94933$$

$$\overline{s}_{13}^{\Lambda} = 492.45368$$

$$\overline{s}_{14}^{\Lambda} = 477.01867$$

$$\overline{s}_{23}^{\Lambda} = 427.27926$$

$$\overline{s}_{24}^{\Lambda} = 421.09534$$

$$\overline{s}_{34}^{\Lambda} = 406.11904$$

$$\begin{aligned} R(\mu, g, m, s, a) &= 3178 (465.94933) + \dots + 6477 (17.14316) \\ &= 9263514.08944 \end{aligned}$$

$$\begin{aligned} \text{S.S. Among R} &= R(\mu, g, m, s, r, a) - R(\mu, g, m, s, a) \\ &= R(\widetilde{r}_{ij}, a) - R(\widetilde{s}_{ij}, m, a) \\ &= 9271632.59087 - 9263514.08944 \\ &= 8118.50143 \end{aligned}$$

$$\begin{aligned} \text{S.S. for Error} &= R(T) - R(\mu, g, m, s, r, a) \\ &= \Sigma y_{ijkl}^2 - R(\widetilde{r}_{ij}, a) \\ &= 9378090 - 9271632.59087 \\ &= 106457.40913 \end{aligned}$$

The d.f. for R = 13 - 10 = 3.

The 13 comes from the number of independent parameters in R (reciprocal crosses, a). The 10 comes from the number of independent parameters in R (reciprocal crosses, m, a). They are: one each for a_1, m_1, m_2, m_3 , and six for the $\widetilde{s}_{ij}$. The d.f. for error = 45 - 13 = 32; the 45 comes from the total number of observations.

	D.F.	S.S.	M.S.	F
Among R	3	8118.50143	2706.16714	0.81
Error	32	106457.40913	3326.79403	

Thus we fail to reject H_0 ; $r_{ij} = 0$.

2. Test of Hypothesis that $\sigma_{ij} = 0$ assuming $r_{ij} = 0$

Test requires $R(\mu, \sigma, m, s, a) - R(\mu, \sigma, m, a)$

Let $d_j = \mu + \sigma_j + m_j$

$R(\mu, \sigma, m, a)$

	a_1	a_2	σ_1	σ_2	σ_3	σ_4	d_1	d_2	d_3	d_4	Sum
a_1	19	0	8	3	6	2	1	4	9	5	8658
a_2	0	26	10	5	5	6	5	5	7	9	11706
σ_1	8	10	18	0	0	0	0	3	7	8	6821
σ_2	3	5	0	8	0	0	4	0	4	0	3461
σ_3	6	5	0	0	11	0	1	4	0	6	4754
σ_4	2	6	0	0	0	8	1	2	5	0	3328
d_1	1	5	0	4	1	1	6	0	0	0	2658
d_2	4	5	3	0	4	2	0	9	0	0	4025
d_3	9	7	7	4	0	5	0	0	16	0	7204
d_4	5	9	8	0	6	0	0	0	0	14	6477

	a_1	a_2	σ_1	σ_2	σ_3	σ_4
d_1	1(.16667)	5(.83333)	0	4(.66667)	1(.16667)	1(.16667)
d_2	4(.44444)	5(.55556)	3(.33333)	0 --	4(.44444)	2(.22220)
d_3	9(.56250)	7(.43750)	7(.43750)	4(.2500)	0 --	5(.31250)
d_4	5(.35714)	9(.64286)	8(.57143)	0 --	6(.42857)	0 --

	a_1	a_2	ε_1	ε_2	ε_3	ε_4	Sum
a_1	10.20737	-10.20737	-.12792	.08333	1.91272	-1.86805	60.67436
a_2	-10.20737	10.20737	+.12797	-.08333	-1.91272	+1.86805	-60.67436
ε_1	.12797	.12797	9.36607	-1.75000	-4.76188	-2.85416	626.44464
ε_2	.08333	-.08333	-1.75000	4.33332	-.66667	-1.91666	-112.00886
ε_3	1.91272	-1.91272	-4.76188	-.66667	6.48415	-1.05555	-253.7277
ε_4	-1.86805	1.86805	-2.85416	-1.91668	-1.05555	5.82639	-260.69436

Equations (a_2 and ε_4 absorbed)					
	a_1	ε_1	ε_2	ε_3	Sum
a_1	20.41474	1.74008	1.95138	3.78077	60.67436
ε_1	-.25594	12.22023	1.10416	-1.90772	626.44464
ε_2	.16666	.16668	6.25000	1.25021	-112.00886
ε_3	3.82544	-3.70633	.38888	7.53970	-253.72775

Iteration Values				
	a_1	ε_1	ε_2	ε_3
1	0	0	0	0
2	3.30330	51.33210	-19.37847	-9.01893
3	2.11933	51.65029	-17.55129	-8.43227
4				
5				
6				

After the iteration values for a_1 , g_1 , g_2 , and g_3 , have "settled down", the values of a_2 and g_4 , and subsequently the values for the $\widetilde{s}_{ij}$ are computed from the normal equations, (on the fifteenth page of the computations.)

Next, the Sums of Squares due to fitting these parameters, $R(\mu, g, m, a)$ are found by summing the products of the estimates times the right-hand sides of the normal equations. Then, the Sum of Squares due to S is given by

$R(\mu, g, m, s, a) - R(\mu, g, m, a)$ and this is tested against the error term $R(T) - R(\mu, g, m, s, a)$; note r_{ij} assumed zero.

Further Hypotheses may be tested, eg.,:

Hypothesis that $m_j = 0$ assuming $r_{ij} = 0$

Hypothesis that $m_j = 0$ assuming $r_{ij} = s_{ij} = 0$

and so on.

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TOP CROSS TESTS AT SEVERAL LOCATIONS

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The general problem of testing inbred lines of livestock is treated by Henderson (1948). Tests on the basis of a line's own performance, top-crossing, single crosses, and three-way crosses are considered. Statistical methods for analyzing balanced and unbalanced designs are developed and/or discussed. Little attention is paid to the implications of variation among sires within incompletely inbred lines.

Inbred Hereford lines have been formed by experiment stations cooperating with W-1. Top-cross tests of a specified set of these inbred lines at several locations would: (1) rank the lines according to general combining ability, and (2) indicate the importance of line $\times$ location interaction and rank these interactions. An interaction of this sort could be due to specific combining ability and/or genotype-environment interaction. Even though the test would not necessarily distinguish these two causes, knowledge of the presence or absence of such line $\times$ location interactions would be important in itself since, with the improvement in transportation facilities and the continuous improvement of artificial insemination techniques, the influence of a bull or line can be spread over an increasingly large geographical area if so desired.

The following model is suggested for such a study:

$$Y_{ijklm} = \mu + g_i + p_j + r_k + gp_{ij} + gr_{ik} + pr_{jk} \\ + gpr_{ijk} + s_{ijkl} + e_{ijklm}$$

Wherein:

g_i : is an effect common to progeny of the i^{th} line; essentially it is one-half the additive genetic value of the i^{th} line.

p_j : is an effect common to progeny born and grown in the j^{th} place; the places are chosen so that variation exists between them in environment and/or genetic composition (pedigree) of the cow herd.

r_k : year of calving.

s_{ijkl} : sires within lines.

In an analysis of variance, the composition of the mean squares would be as shown in Table 1.

In testing beef cattle inbred lines, all of which are far from 100 percent inbred, intraline sire variation in progeny should be considered. The error term involved in the analysis of fixed effects at higher levels is a compound of V_w and V_s , variance within sires and variance between sires within a line, respectively. The implications and method of estimation of the V_s component will be discussed later in the development of details of a specific beef cattle study.

Every reasonable effort should be made to work with a balanced design (equal numbers in subclasses) since the theories of estimation and of significance tests are on more solid ground in this case. Furthermore, the expense and effort of calculation increase greatly as the design becomes more unbalanced.

In designing a study, it is best to start with consideration of a balanced design so as to learn what is the maximum information that may be extracted from the experiment. If a balanced design seems unreasonable to achieve, then one can investigate the effects various sorts and degrees of departure therefrom will have upon the amount of information extractable.

Table 1 indicates the mean squares to be used in testing hypotheses about main effects and interactions.

Using the least squares method, the parameter estimates are:

$$\hat{\mu} = \frac{Y_{....}}{pqrs}$$

$$\hat{\sigma}_i = \frac{Y_{i...}}{qrs} - \hat{\mu}$$

$$\hat{p}_j = \frac{Y_{.j..}}{prs} - \hat{\mu}$$

$$\hat{r}_k = \frac{Y_{..k.}}{pqs} - \hat{\mu}$$

$$\hat{sp}_{ij} = \frac{Y_{ij..}}{rs} - \hat{\mu} - \hat{\sigma}_i - \hat{p}_j$$

$$\hat{sr}_{ik} = \frac{Y_{i.k.}}{qs} - \hat{\mu} - \hat{\sigma}_i - \hat{r}_k$$

$$\hat{spr}_{ijk} = \frac{Y_{ijk.}}{s} - \hat{\mu} - \hat{\sigma}_i - \hat{p}_j - \hat{r}_k - \hat{sp}_{ij} - \hat{sr}_{ik} - \hat{pr}_{jk}$$

The variance - covariance matrix of the least squares estimates is equal to $1/a^i a^j / \hat{V}_e$ where $1/a^i a^j$ is the inverse of the matrix of coefficients of the least squares equations and $\hat{V}_e$ is the mean square for error (in the case considered here $\hat{V}_e = \hat{V}_w + n\hat{V}_s$). An element in this inverse matrix corresponding in position to that of the coefficient of a parameter in its "lead" equation in the matrix of the least squares equations when multiplied by $\hat{V}_e$ gives an estimate of the variance of the parameter estimate in question. The square root of this will be the standard error of the parameter estimate. An estimate of the standard error of a linear function of parameter estimates can then be found. For instance, the standard error of $\hat{g}_a - \hat{g}_b$ or of $\hat{g}_{p_{aj}} - \hat{g}_{p_{bj}}$, etc., can be estimated.

For the case where the parameters are assumed to be randomly drawn from a normal population, Henderson (1946) developed a method of adjusting the least squares estimates to give a best estimate, namely, a maximum likelihood estimate:

"... It is a plausible hypothesis that estimates of above normal size contain interaction and error terms whose sum is positive, and that estimates below average size have in them interaction terms and error terms whose sum is negative. It therefore seems logical to regress the least squares estimate toward zero if we wish to obtain the best estimate of the parameter. What is needed to accomplish this is the regression of the parameter on the least squares estimate of the parameter, say $b(\hat{\phi})$. In the usual regression theory $b(\hat{\phi}) = \frac{E\hat{\phi}\hat{\phi}}{E\hat{\phi}^2}$. This

ratio can always be computed for any particular $\hat{\phi}$. Then

$\hat{\phi} = b(\hat{\phi})\hat{\phi}$ where $\hat{\phi}$ denotes the best estimate and $\hat{\phi}$ denotes the least squares estimate of ϕ ."

If the subclass numbers are unequal, including some vacant subclasses, but the effects are fixed (not random), the above procedures can still be carried out. However, in a model of the complexity considered here it would be necessary to assume certain interactions negligible in order to reduce computational labor, obtain unbiased estimates of some of the effects, and make exact tests of certain hypotheses. If all subclasses are full, the part of the foregoing statement about unbiased estimates and exact tests of hypotheses does not apply.

Some Considerations Regarding a Specific Beef Cattle Study

Weaning weight is a heritable economically important trait and is readily obtainable. For this trait a balanced design seems a reasonable possibility. Correction factors for sex, age of dam, and age of calf, developed externally to the test, would permit the use of bull, steer, and heifer calves within a sire group. A different set of correction factors might apply in each place. A dozen or so cows per bull should guarantee the produce of five calves per sire. Semen-tested bulls and cows known to be breeders should be used.

Since the lines to be worked with are far from 100 percent inbred, sire within lines must be considered significant. This sire effect is a random effect. In the case of unequal subclass numbers, this makes an exact test of the hypothesis $V_G = 0$ impossible. The error term to be used then is $V_W + nV_S$ (see Table 1):

TABLE 1

Source of Variation ^{1/}	Degrees of Freedom	Composition of the Mean Squares ^{2/}
Line (G)	p-1	$V_W + nV_S + qrsn(p/(p-1))V_G$
Place (P)	q-1	$V_W + nV_S + prsn(q/(q-1))V_P$
Year (R)	r-1	$V_W + nV_S + pqsn(r/(r-1))V_R$
GP	(p-1)(q-1)	$V_W + nV_S + rsn(p/(p-1))(q/(q-1))V_{GP}$
GR	(p-1)(r-1)	$V_W + nV_S + qsn(p/(p-1))(r/(r-1))V_{GR}$
PR	(q-1)(r-1)	$V_W + nV_S + psn(q/(q-1))(r/(r-1))V_{PR}$
GPR	(q-1)(p-1)(r-1)	$V_W + nV_S + sn(p/(p-1))(q/(q-1))(r/(r-1))V_{GPR}$
S ^{3/}	pqr(s-1)	$V_W + nV_S$
W (within sires)	pqrs(n-1)	V_W

1/ Line, place, and year are fixed effects. The inclusion of year is to acquire additional data. If the GR interaction is of interest then the year should be a random effect and V_{GR} , V_{PR} , and V_{GPR} would be introduced into the mean squares for G, P, and GP, respectively.

2/ With fixed effects the V_G , V_{GP} , etc., are not conceptually variance components but so depicting them indicates the proper mean squares to be used for significance tests.

3/ Sires within lines, a random effect.

The V_S component might be estimated prior to the experiment proper from:

- (1) Uniformity trials at each of the places considered wherein several bulls from a line would be tested at one such place
- (2) Studies already made of the lines may afford such information

The question of possible heterogeneity of error terms should be considered. Two possible sources of such heterogeneity suggest themselves:

- (1) Might V_W differ from place to place? Data for testing this could come from the two sources mentioned above.

(2) How much might V_S differ for lines at different levels in inbreeding?

Estimating V_S externally to the experiment proper has several advantages:

- (1) The degrees of freedom for the error term $V_W + nV_S$ is increased.
- (2) Heterogeneity of error terms from place to place can be tested.
- (3) Existing pertinent information is made use of.
- (4) A single bull per line per place per year can be used in the experiment proper, thus increasing the number of lines that can be compared in the experiment.

If the number of bulls tested per line varies, this may introduce a question of the relative precision of line testing. This is not being considered here, i.e., only the case of one bull per line, per place, per year is being considered.

Further considerations based upon discussion following presentation of the paper:

- (1) Years should be considered a random effect.
- (2) The model should include sire $\times$ place, sire $\times$ year, and sire $\times$ year $\times$ place interactions. With a balanced design such interactions could be studied. Without the use of artificial insemination it might not be possible to fully implement such an experiment.

A study of the expanded model might aid in deciding how serious omission of some or all of these interactions would be in the estimation of line, line $\times$ place, and line $\times$ year effects.

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